Section 22
Connecticut

Wetlands Restoration Investigation
Leetes Island Salt Marsh
Guilford, Connecticut

March 1994

US Army Corps
of Engineers
New England Division

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Department of the Army
Corps of Engineers, New England Division
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The degraded Leetes Island salt marsh, Guilford, Connecticut was investigated to identify an approach which would restore tidal flows to the extent necessary to restore typical salt marsh communities. The Leetes Island salt marsh plant community dominated by spike grass and glasswort, differs from the plant community of a typical New England salt marsh. Also, common reed, a pest species, has invaded various areas of the marsh. This existing plant community is an apparent result of the combined effects of tidal restriction, draining, and salt hay mowing.

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FOREWORD

This foreword was prepared by the Connecticut Department of Environmental Protection, Office of Long Island Sound Programs for the Leetes Island report.

Leetes Island salt marsh has been drained by a tide gate since 1916 principally to allow for salt marsh haying. Since that time the gate has been replaced several times and the present system was installed in 1957. Typically, the tide gate would be closed during the growing season and opened in the fall and winter.

Drained salt marshes such as this undergo a variety of physical, biological and chemical changes. Biological changes result in large part through the hydrological changes caused by the tide gate. The gate reduces or eliminates the rise and fall of the tides causing a decrease in the salt content of the soil and creek water. This creates ideal soil conditions for the rapid replacement of the productive salt marsh grasses by the pestiferous, tall grass known as common reed (Phragmites australis). This grass forms a dense, almost impenetrable cover which acts as a physical barrier to and reduces usage by wildlife species such as shorebirds, waterfowl and wading birds. The woody stems and leaves do not readily decompose and so the export of nutrients from the marsh is diminished. Common reed areas, due to the rapidity at which large volumes of combustible material form, are prone to repeated fires.

In 1978, there were only 7.6 acres of common reed. Today, this has increased to 11.0 acres. Salt marsh haying coupled with the leakage of tide water through the culvert system have probably slowed the rate of spread of this grass.

A variety of physical changes occur to the soil. The soil in a salt marsh is known as peat, which is composed largely of the decomposing remains of plant material. Organic peats only form when the soil is waterlogged and anaerobic. Under these conditions, iron combines with sulfate (a common constituent in sea water) to form the mineral known as pyrite. Draining of the marsh causes the water table, which is normally within several inches of the surface, to drop several feet. Thus the upper several feet of the soil are now exposed to oxygen or oxidized. Under these conditions, the organic component of the soil decomposes at a very rapid rate.

The most immediate consequence of this decomposition is a long term lowering of the marsh surface elevations, an effect called subsidence. In natural salt marshes in this section of Long Island Sound, typical surface elevations will average between 3.5 feet to 4.5 feet relative to NGVD. However, the elevation data generated by the attached study show that average surface elevations range between 0.5 feet and 1.0 feet NGVD, representing subsidence on the order of three to four feet. The longer subsidence occurs, the less likely that the marsh can be restored. A case in point is the Lost Lake-Great Harbor marsh complex in Guilford. This marsh had been drained by tide gates until a hurricane in the early 1950's removed the tide gate. The surface elevations of this marsh had subsided so much that two-thirds of the wetland could no longer support vegetation because of overly wet soils and prolonged flooding. Forty years later, Lost Lake (a misnomer since this was a marsh) still supports no salt marsh vegetation.

Draining causes chemical changes in the soil which cause the marsh to become a non-point source of water pollution. Specifically, pyrite is unstable when exposed to oxygen. Through a series of chemical reactions, pyrite is converted to sulfuric acid which in turns causes a drastic decrease in soil and creek water pH. Levels as low as 3 to 4 are not uncommon in drained salt marshes. These altered soils are called acid sulphate soils. Under such low pH values, the aluminum associated with natural clays is mobilized and this metal is toxic to aquatic organisms at very low concentrations. Where dissolved oxygen levels have been monitored in drained salt marshes, low dissolved oxygen levels, known as hypoxia, have been observed during the summer months especially following rain storms. It appears that the leachate removes oxygen from the water. Fish kills have been observed in some of these wetlands.

An emerging problem for tidal wetlands throughout the U.S. is the apparent increased rate at which sea level is rising. In marshes where there is an imbalance between rising sea level and vertical peat growth, subsidence and loss of vegetation occurs. Recent studies have shown significant changes in the vegetation of southeastern Connecticut salt marshes which are most likely due to accelerated sea level rise. In southwestern Connecticut, the loss of extensive areas of Salt Marsh Cordgrass is believed to be the result of sea level rise.

Sea level rise impacts are of particular concern in drained and subsided marshes such as Leetes Island where there has been a major imbalance between sea level rise and vertical accretion. Additionally, salt marsh haying is contributing to this imbalance through the removal of plant material that would otherwise decompose and increase the height of the marsh surface.

A recurring problem at the Leetes Island salt marsh is nuisance levels of mosquitoes. The tide gate is the primary cause of this problem largely because the reduction of tidal flows has reduced scour and promotes deposition of sediment in the creeks and ditches. Thus water will not drain freely from the marsh and the intermittent ponding creates ideal breeding habitat for mosquitoes.

Although the tide gate and culvert system have been replaced several times in this century, under current regulatory standards and criteria, replacement of the tide gate could not be permitted since it will cause further wetland degradation, subsidence and water quality problems. The existing structure is in disrepair, and pipe corrosion is causing loss of soil above the pipe.

Recognizing these habitat, water quality and mosquito breeding problems, the DEP contracted with the Corps of Engineers to undertake the attached study in anticipation of finding a remedy that would alleviate these problems. Drained salt marshes such as this have been restored successfully in other coastal Connecticut towns. From a mosquito control standpoint, restoration usually eliminates all breeding since the typical tidal regime in a restored marsh results in flooding most of the marsh surface on a daily basis. Such a flooding regime precludes breeding by the salt marsh mosquito. This is the only feasible mosquito control technique for this wetland since the Connecticut Department of Environmental Protection prohibits the maintenance of mosquito ditches. Restoration would also eliminate any water quality problems resulting from draining. Since common reed is intolerant of tidal water with a salt content greater than 15 parts per thousand (ppt) (Long Island Sound water averages 26 ppt), reed would be replaced by the more productive salt marsh grasses.

The results and recommendations of this study will be discussed with key Guilford municipal commissions and concerned citizens. Funds are available from several different federal and state agencies to proceed with wetland restoration. Assuming there is support for this project, the next step will be to develop a final design plan.

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EXECUTIVE SUMMARY

The degraded Leetes Island salt marsh, Guilford, Connecticut was investigated to identify an approach which would restore tidal flows to the extent necessary to restore typical salt marsh communities. The Leetes Island salt marsh plant community, dominated by spike grass and glasswort, differs from the plant community of a typical New England salt marsh. Also, common reed (Phragmites australis), a pest species, has invaded various areas of the marsh. This existing plant community is an apparent result of the combined effects of tidal restriction, draining, and salt hay mowing.

Tidal exchange between the marsh and Island Bay is controlled by a 42-inch culvert and removable flap gate. The use of the flap gate for several months a year restricts tidal flow to the marsh. Normally, this tidal restriction would result in a change in plant community to species characteristic of less saline conditions, but at Leetes Island marsh salt hay mowing and possibly areas of locally high soil water salinity are apparently deterring the encroachment of a less saline plant community. Previous reports have suggested that if salt hay mowing were discontinued, common reed would rapidly spread and dominate the system.

Estimated tide ranges in Island Bay and measured elevations of the marsh surface indicated restoration of full tidal flow would result in excessive flooding of the marsh. These conditions along with considerations of salt marsh vegetation requirements indicated the goal of the tidal restoration effort should be to attempt to maintain a desired frequency of flooding rather than restoring the full tidal flow to the marsh.

Evaluated structural improvements are intended to allow for adequate tidal exchange to inhibit the growth of common reed and encourage the growth of salt marsh vegetation. In addition, further channelization and/or open water marsh management in the northern areas of the marsh may be required to ensure the restoration of conditions suitable for salt marsh vegetation.

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INTRODUCTION

STUDY AUTHORITY

Authority for the Section 22 "Planning Assistance to States", program is contained in the Water Resources Development Act of 1974, Public Law 93-251, as amended. This program authorizes the US Army, Corps of Engineers (Corps) to cooperate with the States in the preparation of plans for the development, utilization, and conservation of water and related land resources. Section 319 of the Water Resources Act of 1990, Public Law 101-640, authorizes the Secretary of the Army to collect from non-federal entities, fees for the purpose of recovering fifty percent of Section 22 program costs.

The State of Connecticut, Department of Environmental Protection (DEP), Long Island Sound Program, the non-federal cost sharing partner, and the Corps, New England Division entered into two Cost Sharing Agreements to conduct this study. The first in August 1991 and the second in July 1992. Connecticut DEP's match was provided from the Long Island Sound Cleanup Fund.

STUDY PURPOSE

The purpose of this investigation is to assist the Connecticut, Department of Environmental Protection in identifying an approach to restore tidal flows to the extent necessary to restore typical salt marsh communities to the Leetes Island salt marsh. Marsh vegetation differs from the typical New England salt marsh plant community and common reed (a pest species) has invaded various areas of the marsh. The existing tidal flow to the marsh is controlled by a 42-inch culvert and removable flap gate. This tidal control structure allows too much flooding with the gate open, and insufficient flow with the gate closed. Also, the marsh does not drain during low tide.

STUDY SITE AND STUDY SCOPE

The study site is the salt marsh in the vicinity of Leetes Island in Guilford, Connecticut (See Figure 1). The Scope of Study includes the following tasks:

- o determination of the existing tidal regime in the salt marsh

- o elevation survey to obtain information on culverts and marsh surface

- o observation of salinities in tidal creeks and spot locations in the marsh

- description of the existing vegetation

- development of a one-dimensional model of tidal flow

- determination of a tidal regime that would restore natural salt marsh functions and values

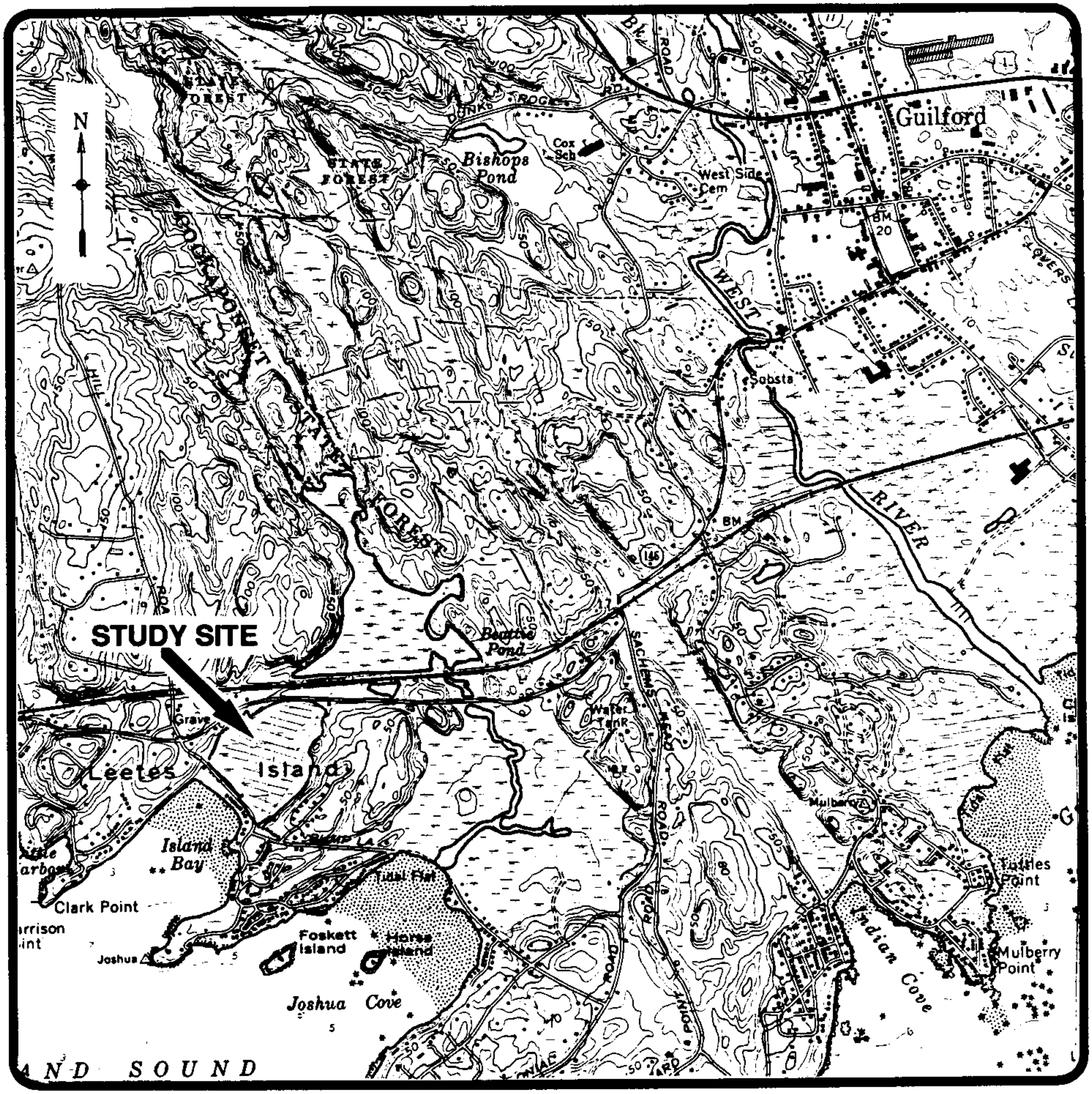
- identification of improvements needed to achieve and maintain the proposed tidal regime and consideration of freshwater hydrology impacts

SITE DESCRIPTION

The Leetes Island salt marsh has a surface area of about 40 acres. The marsh is somewhat rectangular in form and is oriented southwest to northeast. The marsh lies between Shell Beach Road and Leetes Island Road, Route 146 (See Figure 2). The marsh is separated from Island Bay, which opens on to Long Island Sound, by a barrier beach of approximately 200 feet in width. The barrier beach contains Shell Beach Road, about 10 houses facing the bay and a town beach. The culvert and flap gate that carry and control the tide flow from Island Bay into the marsh is located at the southern corner of the barrier beach. Saltwater flow into the marsh is facilitated principally by man made mosquito ditches. A main ditch runs from Shell Beach Road to Leetes Island Road and side ditches for mosquito control have been excavated perpendicular to the main ditch. These ditches break the marsh surface into irregular rectangular polygons.

As early as 1917 a tide gate was installed to regulate tidal flow from the bay into the marsh. Tidal flow control allowed management for salt marsh hay production. In the early 1900's a stone dike was also present along the barrier beach and the existing stone seawall may be part of the original stone dike. Historically, the marsh may have been ditched to drain and dry out the marsh for hay harvesting, but the ditches were also maintained to eliminate habitat of salt marsh mosquitoes (Aedes spp.). It is reported by the Vector Control Section of the Connecticut Department of Health Services, that the main marsh channel was historically a meandering channel about 300 feet north of the existing channel.

The current control structure was installed in 1952 to replace the then existing outfall, wooden tide gate, open ditch, and culvert connecting Island Bay to the main marsh ditch. The current control structure consists of the outfall, a 42-inch diameter corrugated metal pipe encased in concrete and an underground box structure which contains a removable metal flap gate, and about 170 feet of 42-inch diameter culvert connecting to the main marsh ditch. A hole was drilled in the tide gate by the Connecticut DEP in the late 1980's to allow for some inflow of salt water under gate closed conditions.



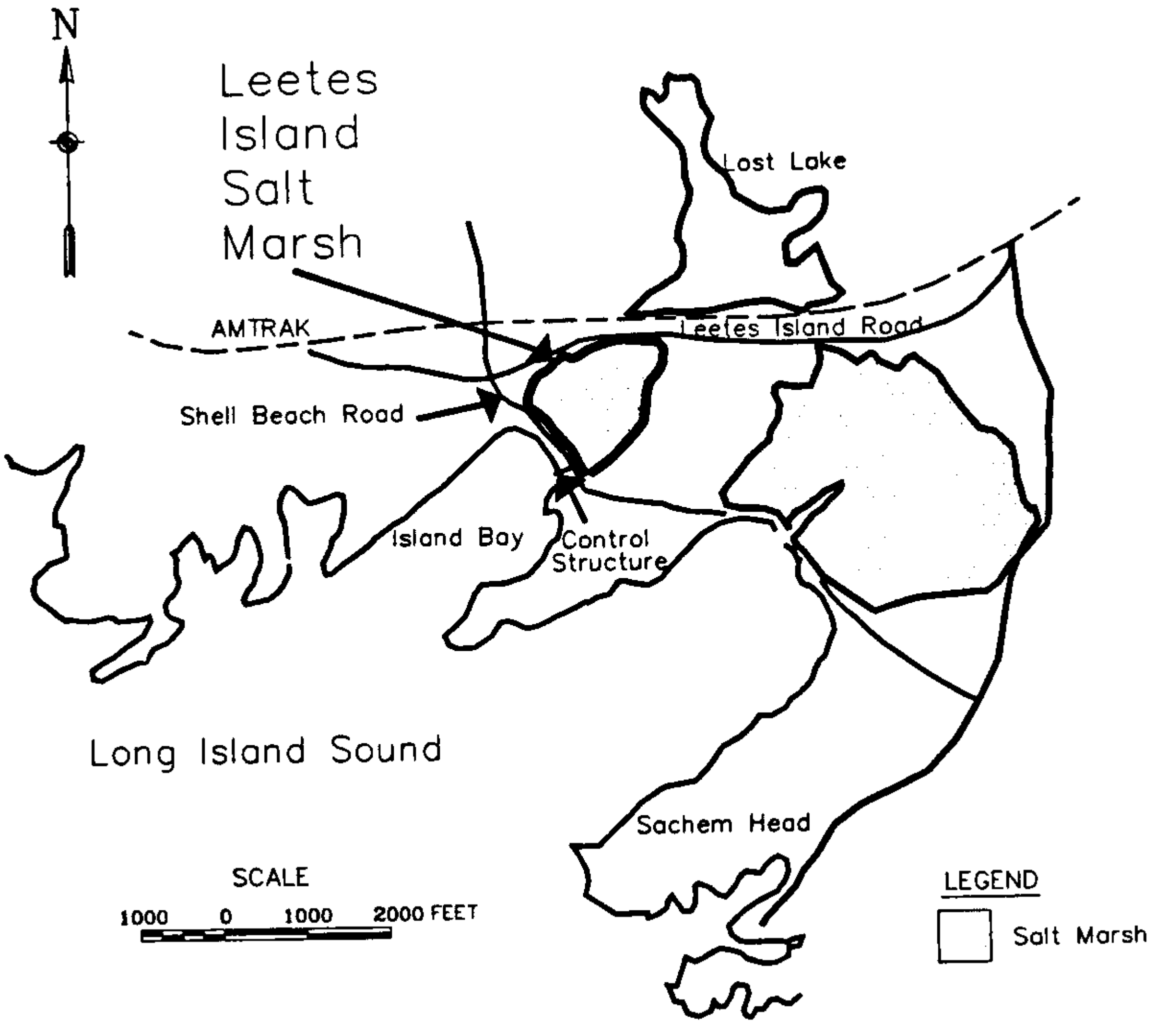
LEETES ISLAND SALT MARSH
LOCATION MAP

USGS 7.5 Minute Quadrangle ,Guilford, Conn.
1968, photorevised, 1984
Scale: 1 inch = 2,000 ft

New England Division

US Army Corps of Engineers

FIGURE 1



LEETES ISLAND SALT MARSH SITE MAP

New England Division

US Army Corps of Engineers

FIGURE 2

The metal flap gate is hinged at the top and opens in a seaward direction. During a rising tide, when the water level in the Sound is higher than the level in the marsh, the gate closes and salt water enters the marsh only through the hole in the gate. When the tide ebbs, the water level in the sound drops below the water level in the marsh and the tide gate opens. Water then flows from the marsh into the Sound.

The marsh is owned by Leetes Brothers, Incorporated. The control structure is reported to be located in an easement deeded to the State of Connecticut, Department of Health Services, Vector Control Section. However, documentation of this easement was not available from the Vector Section. There are two seasonal residences located on either side of the easement.

The existing culvert and flap gate structure is currently operated and maintained by personnel of the Vector Section. The existing flap gate is removed in the fall between late November and early December to avoid ice damage and to flush the marsh. The gate is usually put back in place by May to restrict tidal flow during the growing season. Based on discussions with the Vector Section, it appears the main reason for preventing tidal flow into the marsh from May until November is to to allow drying out of the marsh so that farm equipment can harvest the salt marsh hay. The hay is harvested by Mr. Leete, the marsh owner.

Another culvert, a 12-inch corrugated metal pipe, is located at the upstream end of the marsh near Leetes Island Road. It appears the purpose of this culvert is to drain surface flows from about seven acres of land north of the marsh between Leetes Island Road and the AMTRAK railroad embankment. However, during field investigations, it appeared the pipe was clogged or partially clogged as little flow was observed passing in either direction.

The other hydrologic feature is a small freshwater stream that enters the marsh on the west from high ground off Leetes Island Road. The flow in this stream apparently consists of groundwater seepage and road runoff. Flows from this stream feed into one of the mosquito ditches connected to the main channel.

STUDY METHODOLOGY

FIELD SURVEYS

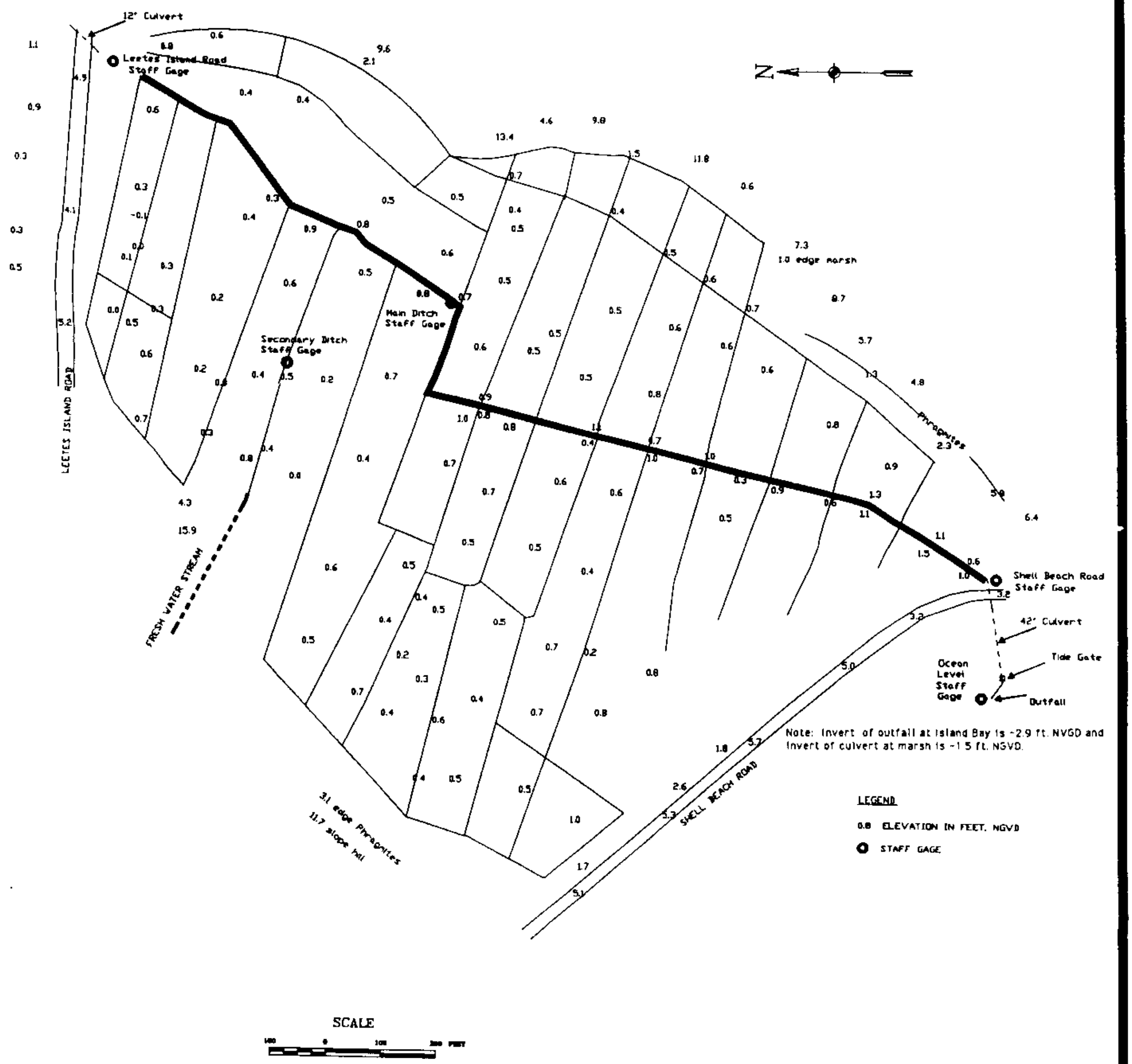
Topographic and tidal monitoring data were collected to determine the existing salt marsh tidal regime, and to obtain information to calibrate and verify a model of one dimensional tidal flow for the marsh. An elevation survey of the area was completed during February 1992. Spot elevations were collected throughout the marsh and adjacent uplands. Vegetation, ditches and other man made structures were also located. Results of the survey are shown in Figure 3.

For tidal monitoring purposes, five staff gages were installed (four within the marsh and one in the bay) and tied to the National Geodetic Vertical Datum (NGVD) to enable tidal movement to be monitored within the bay and marsh area. A gage was mounted on the culvert headwall in Island Bay. In the marsh, gages were mounted on the headwall of the 42-inch culvert at Shell Beach Road, in the main ditch in the center of the main marsh area, on a side ditch in the western portion of the marsh, and at the upper end of the main marsh area at Leetes Island Road. The locations of these gages are shown in Figure 3. Tide data was collected on three different occasions March 19 and April 7 and 16, 1992. The tide gate was off at this time. This data and data analysis are presented in Appendix A, "Hydrologic and Hydraulic Analysis" and Appendix C "Tidal Monitoring Data" and summarized in the following sections.

Vegetation data was collected at the site on March 19 and June 17, 1992. Also 1990 aerial photography was used for vegetation analysis. Soil water, creek, and surface water salinity data were collected at the site on June 17, 1992. This data is presented in Appendix B, Ecological Evaluations and summarized in the following sections.

TIDAL FLOW MODELING

A one dimensional hydrodynamic model, UNET, was selected to analyze hydraulic conditions in the salt marsh in response to various tides and culvert options. Rating curves for culvert options were developed using the Corps HEC-2 backwater computer model. Results of the HEC-2 model were used as input to the UNET model. Modeling of culvert options also considered the occurrence of a freshwater runoff event during the tidal cycle and the potential flooding impacts on areas adjacent to the marsh. As noted above, tide data collected during field surveys were used to calibrate and verify the computer model. Modeling results are presented in Appendix A and summarized in the following sections.



LEETES ISLAND SALT MARSH
SURVEY PLAN
MARCH 1993

New England Division

US Army Corps of Engineers

FIGURE 3

PROBLEM EVALUATION

PROBLEM DESCRIPTION

The high salt marsh plant community of the Leetes Island marsh differs from the plant community of a typical New England salt marsh. This is apparently a result of the combined effects of tidal restriction, draining, and salt hay mowing.

The marsh is dominated by spike grass and common glasswort with salt meadow grass in increasing dominance in the northern portions of the salt marsh. Common reed (Phragmites australis), a pest species in New England marshes, is dominant along the upland perimeter, along the edges of many ditches, and on some broad areas of the marsh (See Figure 4). Staff from Connecticut DEP report that the abundance of Phragmites has decreased in recent years as a result of the amount of salt water which leaks through the hole in the tide gate.

The use of the flap gate restricts tidal flow to the marsh during the growing season. Normally this would result in a change in plant community to species characteristic of less saline conditions, but at Leetes Island marsh salt hay mowing and possibly areas of locally high soil water salinity are apparently deterring the encroachment of a less saline plant community. Previous reports have suggested that if salt hay mowing were discontinued, common reed (Phragmites) would rapidly spread and dominate the system.

Common reed is a species of questionable origin which is increasing in prevalence in New England. It is a relatively low value species ecologically, compared to salt marsh species which are generally recognized as having high ecological value. The tendency of common reed to grow in dense stands which exclude other species of vegetation reduces the benefits which accrue to the marsh environment with diversity of vegetation. Although its productivity is apparently quite high, the value of its biomass is limited. Whereas a portion of salt marsh production is exported to the aquatic and terrestrial food webs, common reed production is, to a large extent, unavailable to food webs. It has relatively low value as a food item because of the coarseness of its stems and leaves and its hairy seeds, although it does provide some value to wildlife as cover.

While the salt hay mowing which presently occurs maintains salt marsh vegetation, the reduction of tidal flooding which occurs with closure of the gates during the summer decreases the value of the marsh as an estuarine habitat. Regular tidal flushing provides a tidal energy subsidy to the marsh and increases the value of the marsh as an aquatic habitat.

Although the marsh presently supports salt marsh vegetation, its productivity is probably reduced because closure of the tides gates reduces the tidal subsidy and maintains a less desired plant community overall. The existing marsh type produces less primary productivity. The reduced frequency of tidal flooding does not allow aquatic organisms to periodically use the marsh. The effects of this reduction in aquatic habitat are most evident along the borders of the marsh creeks and ditches where salt marsh cordgrass would normally be present. This habitat type is normally flooded twice daily, providing an opportunity for feeding by aquatic organisms such as killifish and a permanent habitat for other organisms such as ribbed mussels. Salt hay mowing also reduces the wildlife habitat value of the marsh. Birds and mammals which nest and feed on the marsh such as seaside sparrows and meadow voles are precluded from doing so due to mowing. Therefore, although the the marsh supports salt marsh vegetation, its value is reduced by the current management practice.

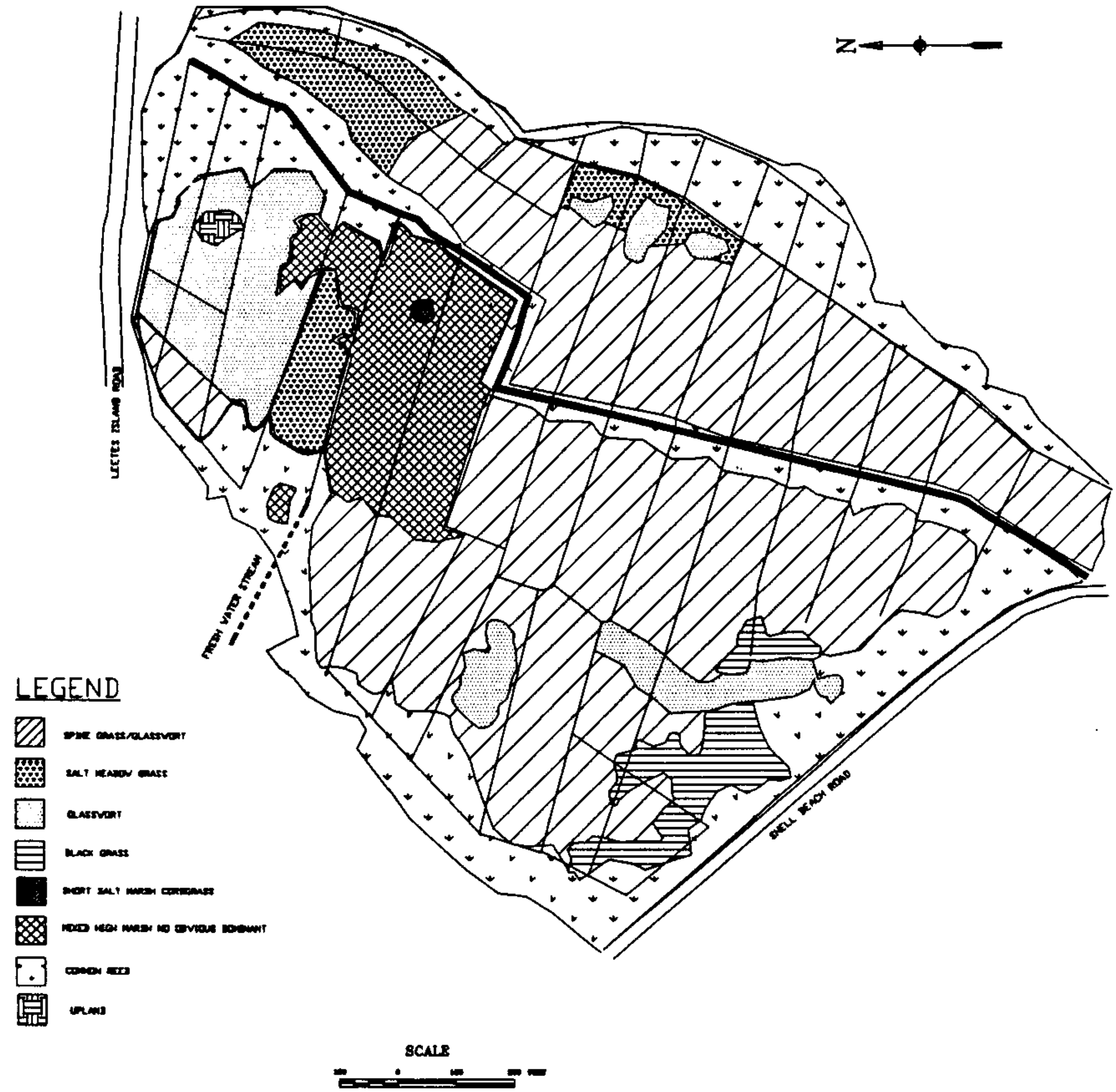
MARSH ELEVATION

Elevation data collected for the surface of the marsh show that in general the greater part of the marsh is fairly flat (0.5 to 1.0 feet NGVD, See Figure 3). However, there are depressions (-0.1 feet NGVD) in the surface of the marsh at the north end near Leetes Island Road. Water ponds on the surface in these depressions and does not drain during low tide conditions.

Although hard to document quantitatively because of inadequate historic topographic data, the elevation of the surface of the marsh may have decreased as a result of marsh draining. Such decreases in marsh elevations are referred to as subsidence.

TIDAL REGIME

Although exact tidal characteristics are not available at the site, an approximation was developed from historical tide data collected at the Bridgeport, Connecticut National Ocean Service Gage (NOS) on Long Island Sound, approximately 25 miles west of the site. Also, tidal flood profiles, developed by the Corps for the open ocean between the primary NOS gages at Bridgeport and New London, CT, were used to estimate tidal flood frequencies at Leetes Island (see Appendix A). A summary of estimated tidal datums at the site is shown in Table 1.



LEETES ISLAND SALT MARSH VEGETATION MAP

New England Division

US Army Corps of Engineers

FIGURE 4

Table 1. Estimated Tidal Datum Planes at Leetes Island

Tidal Event	Tide Level
100-year frequency flood event	10.4
50-year frequency flood event	9.8
10-year frequency flood event	8.2
1-year frequency flood event	5.2
Mean High Water Springs	3.8
Mean High Water	3.4
Mean Tide Level	0.7
Mean Low Water	-2.0

TIDAL MONITORING DATA

The existing tidal regime in the marsh is controlled by the 42-inch culvert and removable flap gate. The gate, which restricts tidal flow, is removed in the fall between late November and early December and put back in place by May. Some salt water leaks through the tide gate due to the poor condition of the gate and culvert and the hole drilled in the tide gate in the late 1980's.

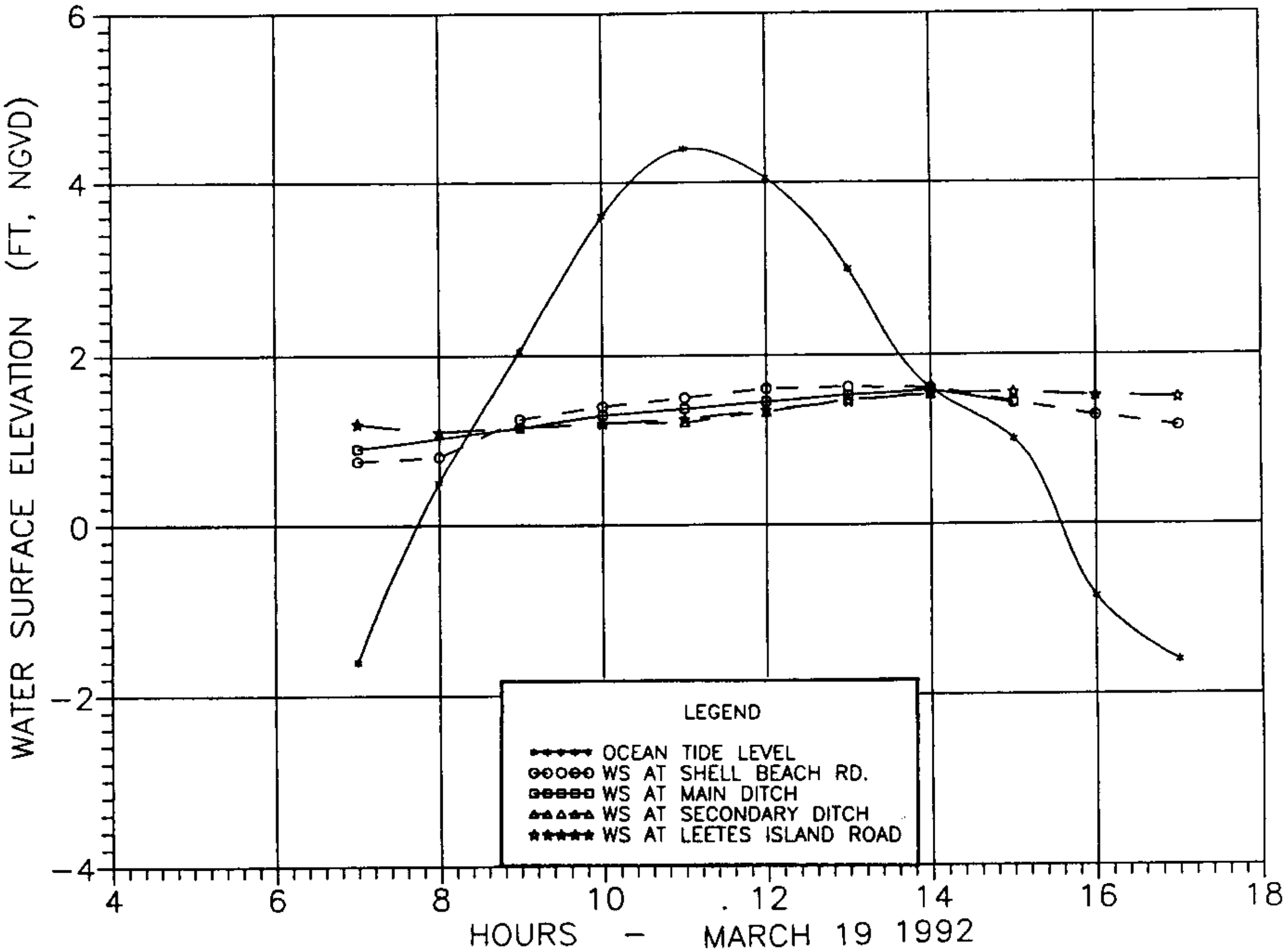
Tide data were collected for three different tide cycles March 19 and April 7 and 16, 1992. Tidal monitoring data was collected with the gate off and tidal flow to the marsh controlled by the existing 42-inch culvert. The intent of data collection was to document the movement of the tidal prism into the marsh. This data was then used to calibrate and verify the computer model and predict the movement of the tide elevation in the marsh with different culvert options. Data from the tidal monitoring event on March 19, 1992 are shown in Figure 5 to illustrate the impact of the existing 42-inch culvert on tidal heights in the marsh. Other data are presented on Plates A-4, A-5, and A-6 in Appendix A and monitoring data are included as Appendix C. The data showed that the existing 42-inch culvert reduces the high tide elevation as much as 3 feet for a spring high tide condition and over 2 feet for a mean high tide condition.

Tidal data and computer modeling of the 42-inch culvert (gate off) show that marsh ditches do not drain fully during low tide conditions because of the restriction imposed by the 42-inch culvert.

SALINITY

Soil water salinity is a significant variable in determining the type of vegetation growing at a given location in a marsh. Literature on the subject indicates growth of common reed occurs at lower soil water salinities. Literature also indicates soil water salinities are influenced by the frequency of flooding of the marsh surface. Observed soil water salinities in the marsh on June 17, 1992 ranged from 14 to 40 parts per thousand (ppt). Soil water salinities appear to be consistent with the type of vegetation observed at sampled locations at Leetes Island marsh. Creek salinity levels ranged from 0-26 ppt generally decreasing to the north. The salinity in Island Bay was 25 ppt consistent with salinities in Long Island Sound. To describe salinity conditions adequately long-term salinity monitoring would be required.

The high relative dominance of spike grass may reflect increased salinity levels in the marsh due to the reduced level of flooding during the growing season when the gate is closed. In the absence of frequent flooding, salts may accumulate through evapotranspiration. This would require long-term monitoring to confirm and conflicts with the suggestion that common reed would dominate the site if salt hay mowing were stopped.



LEETES ISLAND SALT MARSH
TIDAL MEASUREMENTS
MARCH 19, 1992

New England Division
US Army Corps of Engineers

FIGURE 5

SALT MARSH RESTORATION

OBJECTIVE

The objectives of the salt marsh restoration effort at Leetes Island are to:

- inhibit the growth of common reed
- maximize the area that supports typical salt marsh vegetation
- provide adequate marsh drainage for plant growth
- eliminate possible water quality problems caused by draining with the tide gate

PROPOSED TIDAL REGIME

In order to define a proposed tidal regime for the Leetes Island salt marsh several factors were considered including:

- frequency of flooding required to maintain conditions favorable for growth of salt marsh vegetation
- tide ranges in Island Bay
- existing surface elevation of the salt marsh

This information indicated that the goal of the restoration effort should be to maintain a certain frequency of marsh surface flooding rather than restoring the full tidal flow to the marsh. The elevation of the marsh surface is mostly near or below the mean tide level in Island Bay (0.7 feet, NGVD). Salt marsh does not grow below mean tide level since the duration of flooding is too long making the soils water logged. Thus, restoration of full tidal flow during the growing season would result in excessive flooding of the marsh and loss of salt marsh vegetation. Also, if full tidal flow were to be restored a portion of Shell Beach Road would be flooded during some tidal cycles, since a portion of the road is below mean high water (3.4 feet NGVD).

Review of salt marsh vegetation literature indicated that the frequency of flooding criteria presented in Table 2 be used to establish the tidal regime at the marsh (See Appendix B).

Table 2. Criteria for Proposed Tidal Regime

Marsh Component	Frequency of Flooding
Low Marsh	1-2 times/day
High Marsh Plain	2-28 times/month
Upper Border	< 2 times/month

In order to satisfy the frequency of flooding criteria, considering the average frequency of tide heights in the bay and the existing marsh surface elevation, the tidal regime presented in Table 3 is proposed for the Leetes Island marsh.

Table 3. Proposed Tidal Regime

Marsh Component	Average Frequency of Flooding	Estimated Water Surface Elevation Exterior Ocean	Estimated Water Surface Elevation Interior Marsh
Low Marsh	Ranging from		
(Invert to top	2 times/day to	1.7	
of ditch)	1 time/day	3.4	0.5
High Marsh Plain	Ranging from		
(Top of ditch to	1 time/day to	3.4	0.5
upper border)	2 times/month	4.7	0.8-1.0
Upper Border	Less than 2 times/month		
	(approx. 1/month)	5.1	1.3-2.0

Notes:

Exterior (Ocean) elevations were estimated from tides and tidal datums in the United States, Special Report No. 7, dated February 1981, by the U.S. Army Corps of Engineers, Coastal Engineering Research Center.

Interior (marsh) elevations were estimated from spot elevations on base plan surveyed in February 1992.

Frequency of flooding criteria are discussed in Appendix B, Ecological Evaluations.

IDENTIFICATION OF STRUCTURAL IMPROVEMENTS

In order to establish the proposed tidal regime the replacement of the existing control structure is required. Several culvert options were evaluated using the computer model, UNET (see Appendix A). The new culvert was assumed to be located at the site of the present control structure, although an alternative site west of this location may also be feasible.

Culvert Design for Flooding the Marsh - The computer modelling of various culvert options (see Appendix A) indicated that a 24-inch corrugated metal culvert would be the minimum pipe size needed to fill the marsh to the desired level. However, due to limitations in the accuracy of the model and local conditions in the field, it is recommended the a 36-inch culvert be selected, with a sluice gate to fine tune the amount of flooding which takes place.

However, if the culvert under Leetes Island Road at the upper end of the marsh is cleaned or increased in size then the minimum culvert size at Shell Beach Road should be somewhat larger possibly in the 42-inch range to allow for flooding this area. Further channelization may also be required in the northern area of the marsh to feed the area located north of Leetes Island Road.

Culvert Design for Draining the Marsh - Analysis also indicated (see Appendix A) that there would be a problem draining the marsh during low tide conditions for all culverts 42-inches and smaller. A larger culvert would be needed to provide for marsh drainage during ebb tide.

Another option is to lower the bay side culvert invert. However, given the elevation of the beach flats in this area, the invert of the culvert at Island Bay is already at the minimum possible elevation. (The invert of the existing 42-inch culvert at the bay side is -2.9 feet NGVD and at the marsh is -1.5 feet NGVD.) If the invert were lowered further, it would require dredging in the tidal flat area. Dredging was not considered a viable solution due to the maintenance requirements for a channel located at the headwater of a bay subject to open ocean waves.

Computer simulations of mean tide range conditions were conducted to determine the minimum size culvert, which would provide sufficient draining during ebb tide conditions, to lower water surface in the ditches, at least those close to the outlet, significantly below the top of bank. From a large number of culverts initially sized a concrete box culvert 4 feet high by 6 feet wide was selected. (The selection of concrete takes advantage of the smoother friction factor of concrete versus corrugated metal pipe.) The invert in the bay was kept the same, since dredging of tidal flats in the bay would be required to lower it. However, the end of the culvert at the marsh was lowered about 1 foot from -1.5 to -2.5 feet NGVD. The 4 by 6-foot box culvert for draining would have flap gate installed to prevent tidal inflow through the box culvert. The smaller 36-inch culvert and sluice gate would be used to fill the marsh.

Assessment of Flood Impacts - Computer simulations (see Appendix A) were also completed for the 4 by 6-foot box culvert to determine the impact if the flap gate were inadvertently left open for a higher than normal tide level. Two different simulations were completed, the March 19, 1992 tidal event - a high tide condition of 4.4 feet NGVD and an estimated 1-year frequency tidal flood - a high tide condition of 5.2 feet NGVD.

The 4 by 6-foot culvert restricts the tide by about 3 feet, which would still provide some flood protection for the interior. The low area of Shell Beach Road, estimated to be the first area impacted by flooding, is approximately 3.3 feet NGVD. The interior water surface for the March event would rise to approximately 2.0 feet NGVD, while the estimated 1-year frequency event would rise to 2.4 feet NGVD, less than 1 foot below the estimated beginning damage level of 3.3 feet. Any tidal event having a higher ocean level, or significant coincident runoff, may create flooding problems in the interior if the flap gate were left open. Therefore, a positive closure installed with the box culvert is suggested, in case the flap gate gets stuck in the open condition.

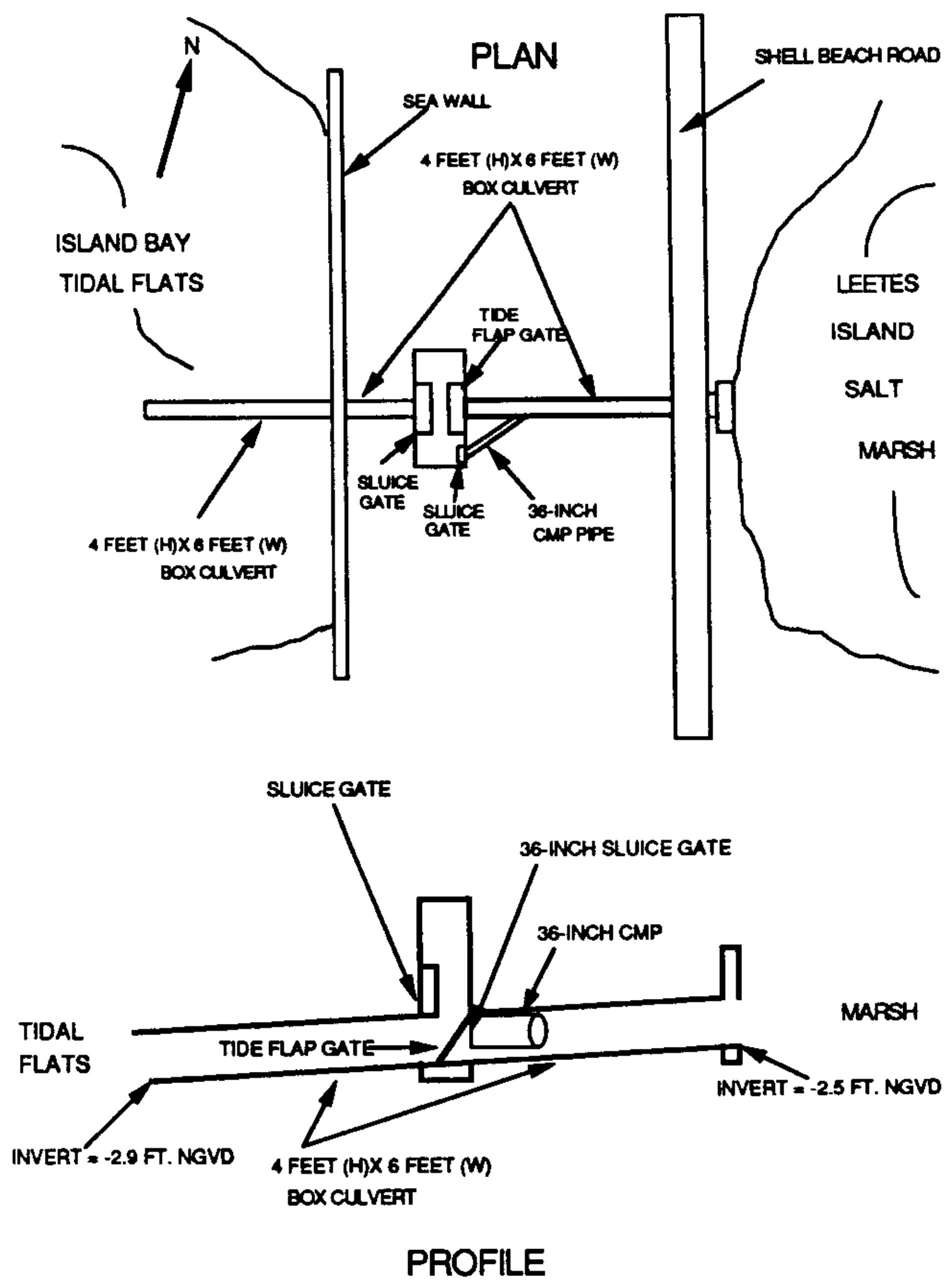
CONCLUSION

Based on the analysis conducted for this report, it appears that a new control structure as shown in Figure 6 would provide for the desired marsh flooding and draining. The new control structure consists of a four-foot high by six-foot wide concrete box culvert with a flap gate (for marsh draining) and a parallel 36-inch culvert and sluice gate (for marsh filling), with a sluice gate installed in front of the culverts to provide for positive closure in case the flap gate were stuck in the open condition.

The water surface levels for the design condition are shown in Figure 7. It is assumed that the sluice gate on the 36-inch culvert would be used to control the amount of flooding in the marsh to the desired elevation. Also reduction in the size of the box culvert may be made if it is determined that the marsh does not have to be drained as quickly or as completely as shown in Figure 7. The proposed culvert was assumed to be located at the site of the present control structure, although an alternative site west of this may also be feasible. Variations on the size of the proposed structure could be tested as part of final design to determine the least expensive feasible option and the best location.

In addition to the proposed control structure, further channelization and/or open water marsh management in the northern areas of the marsh may also be required to ensure the restoration of conditions suitable for salt marsh vegetation.

Issues associated with implementation of structural improvements such as cost, funding, real estate considerations, permit requirements, and land owner permission were not addressed as part of this study.



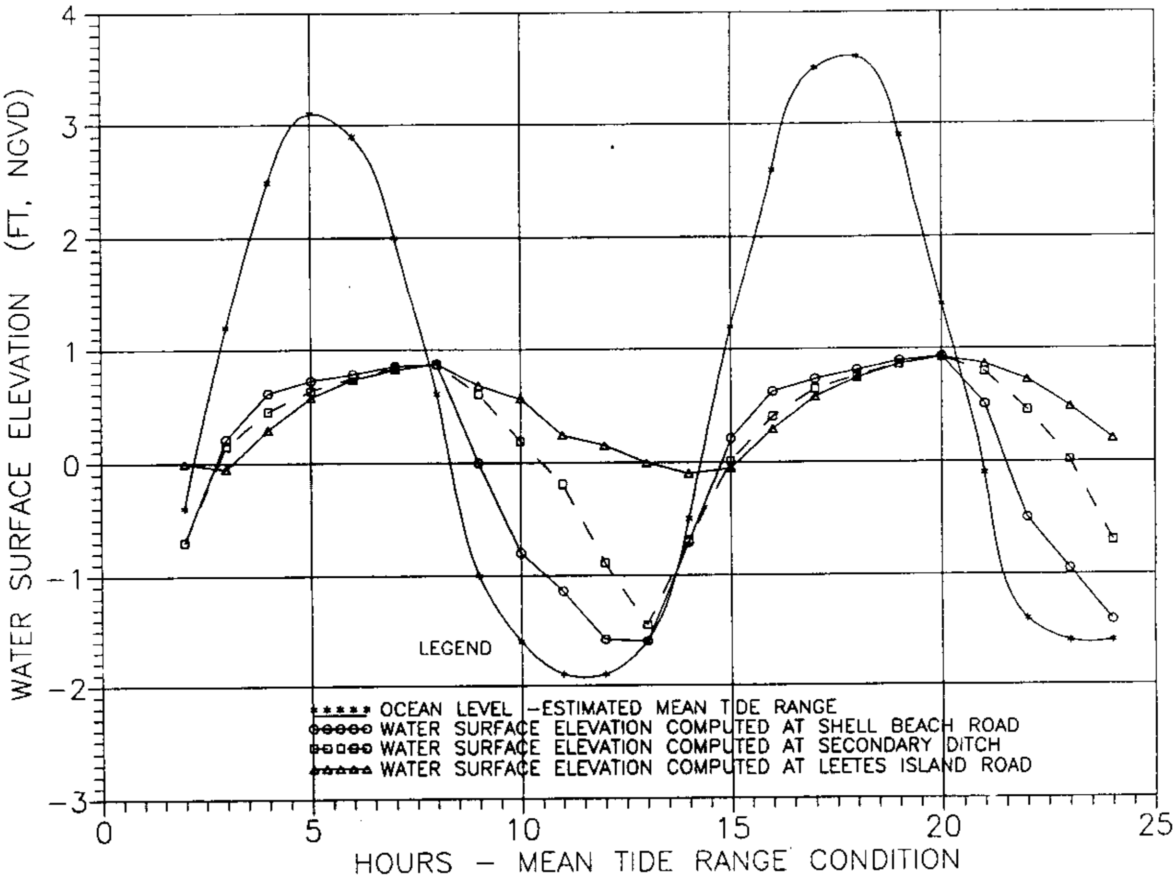
LEETES ISLAND SALT MARSH
SCHEMATIC OF PROPOSED
TIDAL STRUCTURE

not to scale

New England Division

US Army Corps
of Engineers

FIGURE 6



LEETES ISLAND SALT MARSH
Mean tide range with 36-inch inflow culvert and 4X6-foot outflow culvert
(Note : sluice gate on 36-inch culvert can be used to adjust marsh filling)

New England Division

US Army Corps of Engineers

FIGURE 7

APPENDIX A

HYDROLOGIC AND HYDRAULIC ANALYSIS

APPENDIX A

HYDROLOGIC AND HYDRAULIC ANALYSIS FOR WETLANDS RESTORATION INVESTIGATION LEETES ISLAND SALT MARSH GUILFORD, CONNECTICUT

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HYDROLOGIC AND HYDRAULIC ANALYSIS
FOR WETLANDS RESTORATION INVESTIGATION
LEETES ISLAND SALT MARSH
GUILFORD, CONNECTICUT

1. INTRODUCTION

This hydrologic and hydraulic analysis was conducted to provide an assessment of tidal conditions within the Leetes Island salt marsh, and to determine the culvert size and gate structure needed to improve tidal flow conditions in the marsh. This work effort includes development of a one-dimensional model of tidal flow. The existing tidal control structure allows too much tidal flooding with the gate open, and insufficient flow with the gate closed.

2. BACKGROUND

a. Watershed and Salt Marsh Description. The Leetes Island salt marsh watershed has a drainage area of approximately 0.17 square mile,or 110 acres. The primary stream for the marsh is an unnamed brook, which originates approximately one-half mile upstream in a northeasterly direction from Island Bay, a small embayment of Long Island Sound. The brook generally flows in a southwesterly direction, through a small straight channel (containing a few 90 degree bends) to the bay. Land use in the watershed is primarily tidal marsh, with some residential areas. Permanent residences are located on Leetes Island Road and northern Shell Beach Road; seasonal cottages are located on southern Shell Beach Road. Elevations range from approximately 70 feet NGVD, on the eastern and western high ground areas surrounding the marsh, to -2 feet NGVD in larger ditches near the southern end of the watershed (see figure A-1 for the location of the study area).

The brook and adjacent marsh begin on the northern side of Leetes Island Road, and are bounded by the road on the south, the Conrail Railroad track on the north, and high ground on the east and west. There did not appear to be any direct connection between the marsh on the north side of the Conrail Railroad track, and Leetes Island marsh south of the railroad track. The drainage area between Leetes Island Road, and the railroad track contributary to Leetes Island

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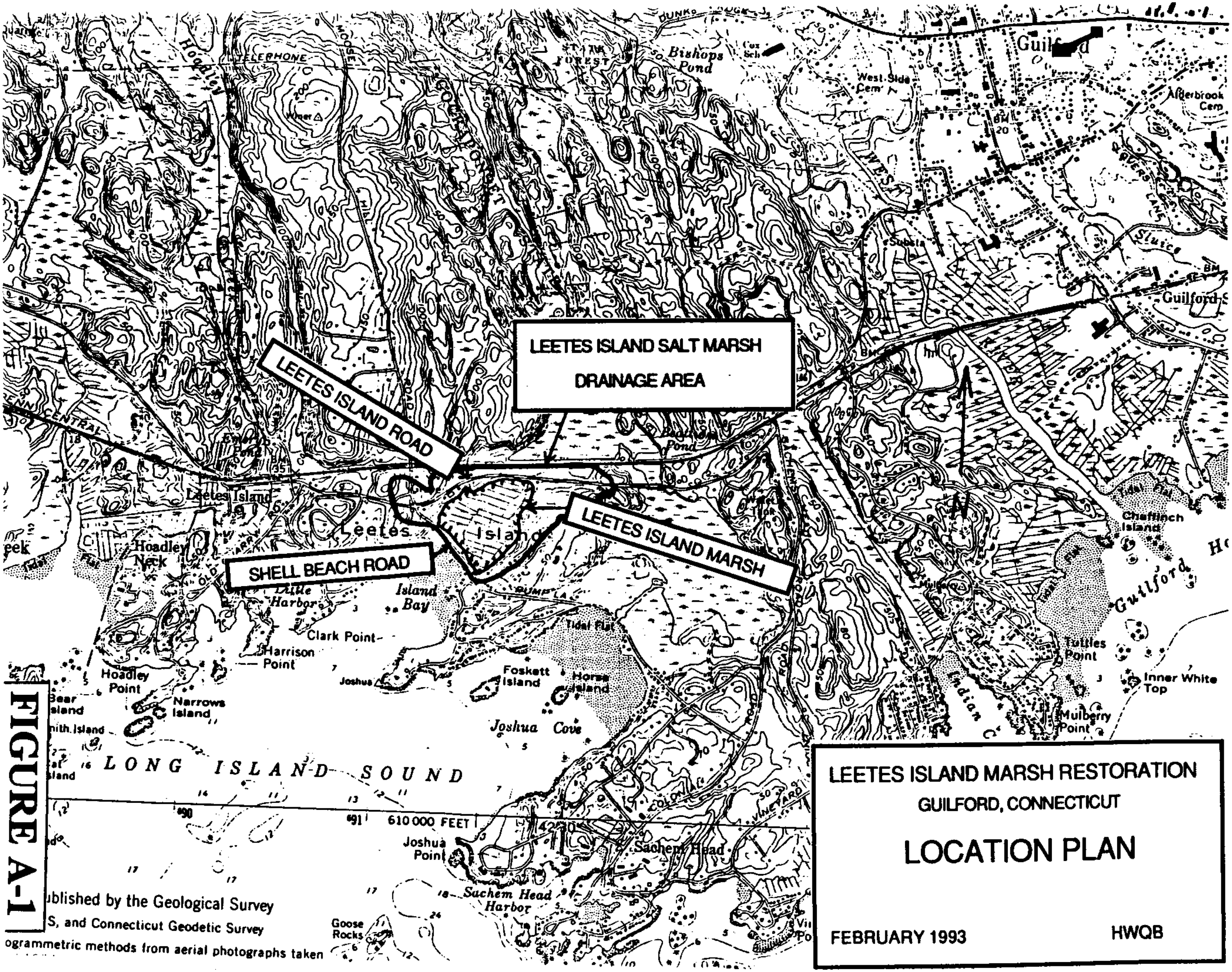

FIGURE A-1

LEETES ISLAND MARSH RESTORATION
GUILFORD, CONNECTICUT

LOCATION PLAN

FEBRUARY 1993 HWQB

marsh is approximately 7 acres. Surface drainage from this area flows under Leetes Island Road through a 12-inch corrugated metal pipe (CMP) culvert. During tidal measurements made in March and April 1992, the 12-inch pipe appeared to be either completely or partially clogged, with no flow passing in either direction. The 12-inch culvert drains into a small ditch on the south side of the road where the major portion of the salt marsh is located. This larger area of marsh is bounded on the north by Leetes Island Road, on the east and west by high ground, and on the south and west by Shell Beach Road. It contains about 40 acres and is about 1,700 feet long and 1,300 feet wide. A small freshwater stream, apparently consisting of groundwater seepage and road runoff, enters the marsh area from high ground off Leetes Island Road on the west. The marsh area is broken into numerous rectangular panels by mosquito ditches, maintained by the State of Connecticut, Department of Health Services Vector Section. Table A-1 shows the approximate area-capacity relationship for the Leetes Island marsh area.

The primary stream channel runs through the marsh area to Shell Beach Road, where it enters a buried 42-inch CMP pipe, passing under Shell Beach Road, and through an easement for a distance of about 170 feet toward the bay. At this point, the pipe enters a rectangular concrete structure where a tidal flap gate is located. This gate can be removed when required. A 42-inch severely corroded CMP culvert exits this structure, passing through a granite block seawall, and extending approximately 50 feet to the tidal flat area. The invert of the culvert, at Shell Beach Road headwall in the marsh is -1.5 feet NGVD, and the invert, as the culvert empties into Island Bay tidal flats, is -2.9 feet NGVD.

b. Description of Problem. Natural tidal flushing of the marsh was interrupted in the early 1900s through construction of a stone dike system and tidal flood gate structure, which allowed for salt marsh hay production. The seawall, which now exists, may be part of the original stone dike. The current control structure, constructed south of Shell Beach Road, was put in place in 1952 to replace the earlier tidal structure. Inadequate sizing of the culvert, and placement of a tidal flap gate within the gate structure, restricts natural tidal flows. The tidal flap gate is usually closed in the summer months to allow salt marsh haying, and opened during the fall and winter, to allow flushing of the sediments that have accumulated in the tide ditches and creek.

By restricting the tidal prism, changes have taken place, which effect the flora and fauna within the marsh as

TABLE A-1

APPROXIMATE
AREA-CAPACITY RELATIONSHIP
LEETES ISLAND SALT MARSH
GUILFORD, CONNECTICUT
(MAIN MARSH AREA)

Elevation (feet, NGVD)	Area (acres)	Cumulative Volume (acre-feet)
-2.0	0	0
-1.0	0.4	0.2
0	1.1	0.9
0.3	1.4	1.3
0.5	9.6	2.4
0.7	22.2	5.6
1.0	32.9	13.8
3.0	38.9	85.6

NOTES:

Area and volume relationships developed from U.S. Army Corps of Engineer Survey completed February 1992.

Main marsh area is bounded by Leetes Island Road on the north, Shell Beach Road on the south, and high ground on the east and west.

described in Appendix B, Ecological Evaluations.

Also, although hard to document quantitatively because of inadequate historic topographic data, land in the tidal marsh may have subsided. This is evidenced by constantly flooded panels existing in the upper end of the marsh area near Leetes Island Road.

Land subsidence may be linked to reduced marsh flushing and salt hay mowing. Long term mowing removes organic matter and less frequent inundation may result in inorganic material within the marsh not being replenished during storm and high spring tides. In addition, a possible lower water table when the gate is in place may result in drying out and compaction of the marsh peat and increased microbial decomposition of the peat.

The natural channels within the marsh were originally altered to ensure drainage for harvesting hay. Recent efforts by the Department of Health Services, Vector Section, have focused on reducing mosquito breeding areas, and improving sediment flushing characteristics through drainage modifications, such as channel straightening and construction of perpendicular side ditches.

Further improvements to marsh management capability would require modification of the simple gated structure and corroded CMP culvert, which is presently the only method to feed tidal water to the marsh area.

3. SITE HYDROLOGY

a. Tidal Regime. In the study area, tides are semi-diurnal, with two high and low water occurring during each lunar day (approximately 24 hours and 50 minutes). The resulting tide range is constantly varying, in response to relative positions of the earth, moon, and sun; the moon having the primary tide producing effect. Maximum tide ranges occur when orbital cycles of these bodies are in phase. A complete sequence of tide ranges is approximately repeated over an interval of 19 years, known as a tidal epoch. Although exact tidal characteristics are not available at the site, an approximation can be developed from historical tide data collected at the Bridgeport, Connecticut National Ocean Service (NOS) gage on Long Island Sound, approximately 25 miles to the west of the study area. Also, tidal flood profiles, developed by the Corps for the open ocean between the primary NOS gages at Bridgeport and New London, CT, were used to estimate tidal flood frequencies at Leetes Island (see plates A-1 and A-2). A summary of estimated tidal datums at the subject site is shown in table A-2.

b. Freshwater Runoff. A preliminary calculation of expected peak freshwater runoff rates and volumes into the marsh was performed, using the "rational" formula and selected 1 and 3-hour rainfall totals, respectively, from the Weather Bureau's Technical Publication 40. The results are presented in table A-3. Coincident high tides and significant runoff from rainfall events must be considered, since high tides occur twice daily, increasing the probability of simultaneous tidal and interior runoff flooding. This analysis assumes that 90 percent of the rainfall, over the 110-acre watershed, enters the marsh as direct runoff. Due to the small drainage area and relatively fast travel times of runoff, routing of peak inflow through ponds and ditches in the marsh was not considered necessary. When evaluating freshwater flood impacts of the proposed structure, total flow was assumed to enter at the upper end of the marsh for this study.

4. METHODOLOGY

a. Data Collection. Topographic and tidal monitoring data were collected to describe the existing salt marsh tidal regime, and to obtain information to calibrate and verify a model of one dimensional tidal flow, for the large area south of Leetes Island Road. A detailed survey of the area was completed during February 1992 to provide adequate information on the topography. This was necessary since the only mapping available was that in the Guilford, CT, U.S. Geological Service quadrangle. Spot elevations were collected throughout the marsh and adjacent uplands. Vegetation, ditches and other manmade structures were also located. Results of the survey are shown in plate A-3.

For tidal monitoring purposes, five staff gages were installed (four within the marsh and one in the bay) and tied to the National Geodetic Vertical Datum (NGVD) to enable tidal movement to be monitored within the marsh area. One gage was mounted on the culvert headwall in Island Bay to provide water levels for the ocean. For interior marsh measurements, one gage was mounted on the headwall of the 42-inch culvert at Shell Beach Road; another, in the main ditch in the center of the main marsh area; one was mounted on a side ditch in the western portion of the marsh; and the

TABLE A-2

ESTIMATED TIDAL DATUM PLANES LEETES ISLAND SALT MARSH GUILFORD, CONNECTICUT

(Estimated from correlation with the Bridgeport, Connecticut National Ocean Service tide gage data and New England Division, Corps of Engineers Tidal Flood Profiles, New England Coastline, dated September 1988)

	Tide Level (ft, NGVD)
100-year Frequency Flood Event	10.4
50-year Frequency Flood Event	9.8
10-year Frequency Flood Event	8.2
1-year Frequency Flood Event	5.2
Maximum Predicted Astronomical High Water	5.2
Mean High Water Springs (MHWS)	3.8
Mean Higher High Water (MHHW)	3.7
Mean High Water (MHW)	3.4
Minimum Predicted Astronomical High Water	1.7
Mean Tide Level (MTL)	0.7
National Geodetic Vertical Datum (NGVD)	0.0
Maximum Predicted Astronomical Low Water	-0.5
Mean Low Water (MLW)	-2.0
Mean Lower Low Water (MLLW)	-2.2
Minimum Predicted Astronomical Low Water	-3.7

TABLE A-3

LEETES ISLAND MARSH, CONNECTICUT
FRESHWATER RUNOFF
(Total Drainage Area = 110 acres)

Return Frequency (years)	Discharge (cfs)	Volume (acre-ft)
5	76	15
10	122	23
50	158	30
100	177	34

NOTE:

Volumes for these runoff events were based on a 3-hour duration triangular hydrograph.

last gage, at the upper end of the main marsh area at Leetes Island Road. The locations of these gages are shown in plate A-3. The inverts of all gages were extended to approximate ocean mean low water to monitor ebb tide conditions. As it turned out, this was not necessary, since the tide did not extend below ocean mean tide level for any of the interior marsh gages, and only dropped down to -1.5 feet NGVD at Island Bay. The reason for the high water level in Island Bay (mean low water is estimated at -2.0 feet NGVD) is because backwater caused by alluvial and coastal deposition, prevents water from freely discharging into the bay. The gradient of the tidal flat area at the outlet is also very slight. Dredging of a channel would be required to lower the water level at the outlet any further.

Tidal data collected at the Leetes Island marsh were referenced to National Geodetic Vertical Datum (NGVD), to allow correlation with data from the nearest NOS gage (Bridgeport, CT). The correlation allows NED to assign important statistical tidal datum planes to the Leetes Island marsh based on historic data collected at the NOS gage (see table A-2). These relationships are the basis for any predictive analysis completed at Leetes Island.

Tide data were collected for three different partial tide cycles during 19 March, and 7 and 16 April 1992. The intent of data collection was to document the movement of the tidal prism into the marsh. This data could then be used to develop a mathematical model to predict interior tidal conditions for various culvert sizes. In general, for the days studied, the data showed that the existing culvert provides a significant reduction to the tidal regime, which exists in Long Island Sound, reducing high tide elevations as much as 3 feet for a spring high tide condition, and over 2 feet for a mean high tide condition. Measurements have shown that the marsh is fully inundated at high tide for tide conditions, monitored during March and April, except at the extreme upper border of the marsh. The marsh panels were inundated by approximately 1 to 2 feet of water under current conditions, with the gate on the 42-inch culvert left removed.

In addition, data show that, generally, the marsh never ends up draining during a low tide condition, because of the restriction imposed by the 42-inch culvert. The phenomena of not draining for a tidal estuary is not unusual. As the tide gets lower and lower, friction effects of the channel bottom and sides have more impact on flow rates, resulting in slower draining during outgoing ebb tide than in higher level incoming flood tides. Tide levels measured within the marsh were generally above 0.5 foot NGVD at all times during low tide conditions. Plates A-4 through A-6 show the results of tidal measurements throughout the salt marsh.

Note that on only one occasion (19 March) were observed tide levels in Long Island Sound significantly higher than that predicted (about 1 foot) due to a storm occurring on that day.

b. Selection of Computer Model. Analysis of any problem is generally restricted by time and budget constraints. This in turn influences the amount of data that can be collected, and controls selection of the tools needed to evaluate and predict effects of the proposed solution. Although, a two-dimensional hydrodynamic model may produce the most accurate representation of hydraulic characteristics of a dendritic-shaped marsh, the necessary data collection program, and difficulties encountered in developing this type of model, would be significant. Two-dimensional models do not handle marsh wetting and drying or confined conduit flow very well. In the case of Leetes Island, a simpler one-dimensional hydrodynamic model, UNET, was selected for the analysis since it is the latest, most advanced model readily available and would provide reasonable results without some difficulties of a 2-D model. The Corps developed this model through its Hydrologic Engineering Center and New England Division was able to obtain an advance copy of the computer code to initiate the study. The very first, fully-documented version of this model was not available until September 1992.

UNET, using the properties of continuity and momentum, applies a linearized, implicit finite difference scheme to solve a set of linear equations. The equations are linearized, using the first order Taylor approximation. The program can simulate one-dimensional unsteady flow through a full network of open channels. For subcritical flow, stages are a function of channel geometry, and downstream backwater effects. UNET provides the user with the ability to apply several external and internal boundary conditions, including flow and stage hydrographs, bridges, spillways, levee systems, and culverts. Cross sections are inputted in a modified HEC-2 forewater format.

Although the UNET model can develop rating curves for culverts using inherent Federal Highway Administration nomographs, it was decided to develop rating curves for the Leetes Island study independently, using the Corps HEC-2 backwater computer model. With this approach, minor changes in culvert construction could be evaluated separately. Results of the HEC-2 model were used as input into the UNET model.

5. RESULTS

a. Model Calibration. Water surface elevations, measured on 19 March 1992, were used to calibrate the UNET model. Estimated existing cross sectional information, and rating curves for the culvert structure, were used initially when running the model. Manning's frictional "n" values (ranged from 0.02 in the channel to 0.1 on the overbanks) and expansion and contraction coefficients (0.5 and 0.3, respectively) were adjusted and minor changes made to the cross sections so results more closely matched the observed tide level measurements. The minor adjustments to the cross sections can be easily justified since the changes were very minor, and of those sections adjusted, affected only a small percentage of the permanently wetted ditch area (approximately 10%).

In addition, it was necessary to input tidal water surface levels for the ocean for the preceding two days leading up to the measurement, since as in the real situation, water levels build up in the marsh due to inadequate capacity of the outlet pipe. Running the model for the preceding two days also removes some of the instability in the calculations, inherent within the finite-difference computer model. Tidal conditions at Bridgeport were used to estimate levels at Island Bay for the previous two days.

Results of the calibrated run for 19 March is shown in plates A-7 through A-9 for locations where tide measurements were collected in the wetlands. As can be seen, the computed results match very closely to the observed data; the high tide levels matching almost exactly and the low tide levels being 0.1 to 0.2 higher than observed.

b. Model Verification. After calibrating the 19 March 1992 data, the model was run again for the other two measured events--on 7 and 16 April 1992. Results of the verification runs are presented in plates A-10 through A-12 and plates A-13 through A-15, respectively. There is a very good match for these dates, and the model was considered to be calibrated and verified to the degree needed for accurate predictive results.

c. Evaluation of Culvert Sizes

(1) General. Numerous culvert sizes were evaluated for this study to design one which would meet requirements of the new marsh regime, proposed in Appendix B, Ecological Evaluations. As stated in this report, the proposed criteria

for marsh restoration should be based on frequency of flooding within the marsh. Because the land surface in the marsh may have subsided as a result of former and current management practices, land areas, which would usually remain dry in the marsh, have now become wet for the same frequency tide. To restore the marsh to its original ecological condition, it is necessary, in the short term, to reduce the frequency of occurrence of tidal inundation in the marsh. This means that some form of control must be placed on the inlet to regulate the flow of tidal water into the marsh. Table A-4 summarizes the frequency of flooding criteria, and associated water surface elevations recommended for the new hydraulic regime of the marsh and compares it to open ocean water levels at the same frequency of occurrences.

Note that table A-4 compares elevations on the exterior or open ocean side to corresponding interior marsh side. This does not mean that the predeveloped marsh (existing before the early 1900s) would have had similar characteristics, occurring at similar elevations, to a marsh located on the open ocean. Naturally occurring tidal restrictions into Leetes Island marsh would have, in all probability, created an interior tidal regime with lowered high tide limits, and with less tide range separating the marsh components. This information describing the predeveloped interior tidal regime, however, is unavailable due to lack of historical data. Therefore, table A-4 should only be used as an indication of the tide range potential that exists for developing an interior marsh. Careful monitoring and operation of any tidal regulating structure will optimize the tidal conditions, which can develop within the marsh.

(2) Culvert Design for Flooding the Marsh. The intent of this investigation is to design a culvert large enough to flood the marsh up to the level of the top of the ditch twice each day (low marsh), and flood the overbank areas and panels on an average of 2 to 28 times/month. The top of the ditch is approximately 0.5 foot NGVD, while elevations of the marsh in the overbanks, are only a few tenths more (0.7 to 0.8 foot NGVD). Flooding higher than approximately 1.3 to 2.0 feet NGVD should occur roughly two times/month or less. With land subsidence caused by man's previous activities, the present elevational range of various marsh zones is narrower than a marsh area located on the open ocean. As a result, controlling water levels in the changed marsh area to redevelop distinctly different ecological zones will be more difficult than an area not subsided. To meet the criteria, a sluice gate should be provided on a small sized pipe, to allow a fine degree of control on admitting tidal flow. The pipe size would have to be smaller than the

TABLE A-4

NEW TIDAL REGIME
LEETES ISLAND SALT MARSH
GUILFORD, CONNECTICUT

Marsh Component	Average Frequency of Flooding	Estimated Water Surface Elevation Exterior Ocean	Estimated Water Surface Elevation Interior Marsh
Low Marsh (Invert to top of ditch)	Ranging from 2 times/day to 1 time/day	1.7 3.4	 0.5
High Marsh Plain (Top of ditch to upper border)	Ranging from 1 time/day to 2 times/month	3.4 4.7	0.5 0.8-1.0
Upper Border	Less than 2/month (approx. 1/month)	5.1	1.3-2.0

NOTES:

Exterior (Ocean) elevations were estimated from Tides and Tidal Datums in the United States, Special Report No. 7, dated Feb. 1981, by the U.S. Army Corps of Engineers, Coastal Engineering Research Center.

Interior (marsh) elevations were estimated from spot elevations on base plan surveyed in February 1992.

Frequency of flooding estimates were taken from Appendix B, Ecological Evaluations.

existing 42-inch culvert, since tidal measurements from the existing pipe provides marsh flooding higher than 0.5 foot NGVD at all times.

Further evaluation was completed when an approximate mean high tide condition was simulated for a 42-inch CMP pipe, using the model (see plate A-16). This approximate mean high tide condition produced water levels significantly higher than the 0.5 foot NGVD elevation, which would exceed the required criteria for flooding the high marsh area less than once per day. It should also be noted that pipes this size (42-inch), and smaller, would create permanently flooded marsh conditions, because of their inability to drain at low tide. Refer to the following section on draining the marsh during low tide conditions.

Various pipe sizes smaller than 42-inch were evaluated, using computer simulation, in an effort to determine which minimum size pipe would be required to allow marsh flooding, up to approximately 0.5 foot NGVD, during a mean tide condition. This elevation as shown in table A-4 would be the criteria for establishing a low marsh area. As shown in plate A-17, the minimum pipe, which would flood the ditch during a normal mean high tide condition, is 24 inches.

Two other scenarios were also simulated assuming a 24-inch pipe was the only outlet (see plate A-18). Because of lack of drainage occurring with a smaller pipe, antecedent high tides have a significant effect on heights that water levels reach during a simulated tide. In examples shown in plate A-18, there are several antecedent flood tides slightly greater than mean tide condition, which would result in higher than normal water surface elevations in the marsh for the tide conditions shown. The first simulation depicts a spring high tide condition (ocean high tide occurs at approximate hour 11), and shows that tide flood water from a 24-inch culvert rises to approximate elevation 0.9 foot NGVD, only slightly overbank in the marsh. Only a portion of the high marsh area between elevations of 0.8 to 1.0 foot NGVD is flooded under this scenario. The 24-inch is not sufficient in size to flood upper levels of the marsh during a mean spring tide condition, which has a average frequency of occurrence estimated at 15 times per month. The second scenario simulated was occurrence of an estimated 3-hour duration, freshwater runoff event, having a peak flow of approximately 177 cfs (see table A-3 for 100-year frequency event) during a mean tide condition (ocean high tide occurs at approximate hour 24). As can be seen for this flood condition, elevations in the marsh would rise to approximately 2.5 feet NGVD, which are lower than the area on Shell Beach Road (3.3 feet NGVD), see plate 3. The 24-inch pipe does not appear to be a problem for draining this freshwater flood event. For comparison purposes, a 42-inch pipe was also simulated, using the same freshwater floodflow and a mean tide condition. As can be seen in plate A-18, for the 42-inch pipe, water surface levels rise to approximately 1.5 feet NGVD during the spring high tide condition and 2.7 feet NGVD for the freshwater flood event. The 2.7 foot NGVD level is still less than the 3.3 foot low point of Shell Beach Road.

Due to inherent inaccuracies of any computer simulation, as well as the problem of insufficient capacity of the 24-inch pipe as presented in plate A-18, conservatively, it is recommended that the pipe be made somewhat larger, possibly 36-inch and have a sluice gate to fine tune the flooding that takes place. Adjustments, using the sluice gate, could be made in the field to account for local probems or changes in drainage.

Due to the adequate capacity of the single culvert in flooding the marsh, it was not necessary to provide another culvert elsewhere. As a result no further analysis was completed on this option.

On a related item, if the culvert under the Leetes Island Road, at the upper end of the marsh (currently 12-inch), is cleaned or increased in size, the minimum pipe at Shell Beach Road should be somewhat larger, possibly in the 42-inch range to allow for flooding of this area. Pipe sizing, related to conveying water to and from the area north of Leetes Island Road, can only be estimated at this time because our efforts were not concentrated on restoring marsh in this area. Further channelization may also be required, in the northern area of the main marsh, to feed the marsh located north of Leetes Island Road since there appeared to be significant restrictions of water reaching this area.

(3) Culvert Design for Draining the Marsh. As shown in plate A-17, there will be a severe problem draining during low tide conditions for all pipes 42 inches and smaller. Significant draining can only take place by enlarging the culvert greater than this size. Lowering the pipe would be another solution; however, as noted in the field, the invert of the existing pipe in the Island Bay flats is already at its minimum possible depth. If the invert were lowered any further, it would require dredging take place in the Island Bay tidal flat area. Dredging of the tidal flat area was not considered a viable solution, due to maintenance requirements for a channel located at the headwater of a bay, which is subject to open ocean waves.

There are a number of arrangements which could be used, to provide adequate conveyance of tidewaters to permit draining of the marsh, and still allow limited flooding up to elevation 0.5 foot NGVD during mean high tide condition, and about 1 foot NGVD during mean spring high tide conditions. All scenarios involve the construction of a much larger culvert than that needed to flood the marsh (36-inch). Each scenario would have a type of control to restrict floodflows, so that only enough inflow is supplied to flood appropriate areas, but on ebb tide, would open wider so that there would be less restriction to allow complete drainage. Various arrangements, which have been in use in previous projects, include using electronic gate control for a sluice gate, elevation sensors to monitor upstream and downstream water levels, and the use of the "Steinke" self-regulating gate, similar to the one previously employed by the State of Connecticut Department of Environmental Protection in Milford.

Another solution would be to provide a parallel type of pipe system. A larger pipe with a flap gate would be installed, which would only open on outgoing tides when the ocean level is less than the interior. A smaller bypass would be constructed parallel to the larger pipe, which would be left open at all times, with the only control being a sluice gate enabling the DEP to adjust flow rates to fine tune water levels within the marsh. For economic reasons, the smaller pipe would only need to be parallel to the larger pipe for a short distance, since it could tie back into the main conduit. The arrangement is shown in plate A-19. In this way, once the sluice gate on the smaller pipe is adjusted properly to allow sufficient flooding in the marsh, there will be no adjustment of the remaining gate structure, other than periodically ensuring that the flap gate on the larger culvert is closing properly. A chain hoist type of arrangement could be installed to open the flap gate of the larger culvert, if fuller than normal tide marsh inundation is required periodically. This arrangement would be less of a problem from an operation and maintenance viewpoint than the electronic arrangement, and would have similar characteristics to those of the "Steinke" gate control system.

Computer simulations of mean tide conditions were conducted to determine the minimum large culvert, which would provide sufficient draining during ebb tide conditions, to lower water surface in the ditches, at least close to the outlet, significantly below the top of bank. From a large number of culverts initially sized, it was narrowed down to concrete box culverts 4 feet high by 4, 6, and 8 feet wide. The selection of concrete was necessary to take into account the much smoother friction factor of the material (0.013) than the CMP pipe (0.025). The invert was originally kept the same as the existing 42-inch pipe. When this did not provide sufficient drainage for the marsh, the invert in the bay was kept the same, since dredging of mudflats in the bay would be required to lower it. However, the upper end of the larger culvert at the marsh was lowered about 1 foot from -1.5 to -2.5 NGVD. This created sufficient capacity to have a significant impact on the interior low tide levels (see plate 20 for the simulations completed). As can be seen, the 4 by 6 foot and 4 by 8-foot culverts provide adequate drainage for marsh ditches during ebb tide conditions.

Water surface elevations are based on both flood and ebb tide occurring through the larger culvert, with an open flap gate, since this would provide conservative assumption of the drainage capability during low tide, and conservative assumption of any flooding problems related to an open flap gate. Actual tidal movement would have similar characteristics of the 36-inch culvert during flood tide (see plate A-17), and would have similar characteristics of the 4 by 6-foot culvert during ebb tide. Water surface in the interior for this type of arrangement, assuming a fully opened sluice gate on the 36-inch pipe during a mean tide condition, would rise to approximate elevation 0.9 foot NGVD rather than the 1.1 foot NGVD elevation shown in plate A-17. The water surface levels for the design condition with a 36-inch inflow pipe culvert and a 4 feet X 6 feet outflow box culvert is shown in Plate 20A. Further reduction in the size of the box culvert may take place during final design analysis if it is determined that the wetland does not have to be drained as quickly or as completely as that shown in Plate 20A.

Computer simulations were also completed for the proposed 4 by 6 foot box culvert to determine what the impact would be if the tide gate were inadvertently left open for a higher than normal tide level. Two different simulations were completed--the 19 March 1992 tidal event and an estimated 1-year frequency tidal flood. The March tidal event was selected since the high tide elevation was approximately one-half foot higher than the mean spring high tide (4.4 versus 3.8 feet NGVD). The other event had a high tide condition of 5.2 feet NGVD, which is the estimated 1-year frequency tidal flood event. Plate 21 is a plot of the simulations. The 4 by 6-foot culvert restricts the tide by approximately 3 feet, which would still provide some flood protection for the interior. No coincident interior flood runoff was included, which would increase interior levels.

The low area of Shell Beach Road, estimated to be the first area impacted by flooding, is approximately 3.3 feet NGVD. The interior water surface for the March event would rise only to approximately 2.0 feet NGVD, while that for the estimated 1-year frequency event rose to 2.4 feet NGVD, less than 1 foot below the estimated beginning damage level of 3.3 feet. Any tidal event having a higher ocean level, or significant coincident runoff, may create severe flooding problems in the interior if the flap gate were left open. Therefore, for any pipe recommended, there must be a form of positive closure installed on the culvert, in case the flap gate gets stuck in the open condition.

6. SUMMARY AND RECOMMENDATIONS

Measurements of tidal movement in the marsh, during observed March and April events, show that most portions of the marsh are sometimes fully inundated, except at the extreme upper border of the marsh. Water depths on the panels for the events measured, were approximately 1 to 2 feet under current conditions, with the tide flap gate on the 42-inch culvert removed. Portions of the marsh in the northerly end are apparently inundated at all times, due to what appears to be subsidence of the historic high marsh area. The marsh north of Leetes Island Road did not appear affected by tidal flood flows during nonstorm conditions, due to inadequate channelization of the marsh in the northerly end and the clogged or inadequately sized 12-inch culvert under the road.

A one-dimensional hydrodynamic computer model, developed by HEC (UNET), was used to simulate tidal movement into and out of the estuary. The model was calibrated and verified on water surface elevations, and collected in March and April 1992, and then used to predict tidal movement for various culvert sizes. Selection of the culvert sizes are based on criteria presented in Appendix B, Ecological Evaluations which indicate: during mean high tide conditions, water levels in the marsh should reach the top of ditch level (approximately 0.5 foot), during mean spring high tide, water levels should reach the furthest limits of the panels within the marsh (approximately 0.8 to 1.0 foot NGVD); and approximately two times a month, the water level should reach approximate elevations 1.3 to 2.0 feet NGVD.

Based on the completed analysis, the minimum pipe size needed to fill the marsh to a desired level would be a 24-inch CMP culvert, although due to inaccuracies of the model, inability to drain, and local conditions in the field, it is recommended that the minimum size be 36 inches, with a sluice gate provided to adjust the flow rates. Also, since use of a small culvert would cause increased ponding, with no draining during ebb tide conditions, a much larger concrete box culvert (4 foot high X 6-foot wide) is recommended, which can be constructed parallel to the smaller culvert. The 4 by 6-foot culvert should have a flap gate installed to prevent tidal flooding during flood tide conditions, but would allow draining during ebb tide. It should also have a sluice gate for providing positive closure during coastal storm events, if the flap gate would not close.

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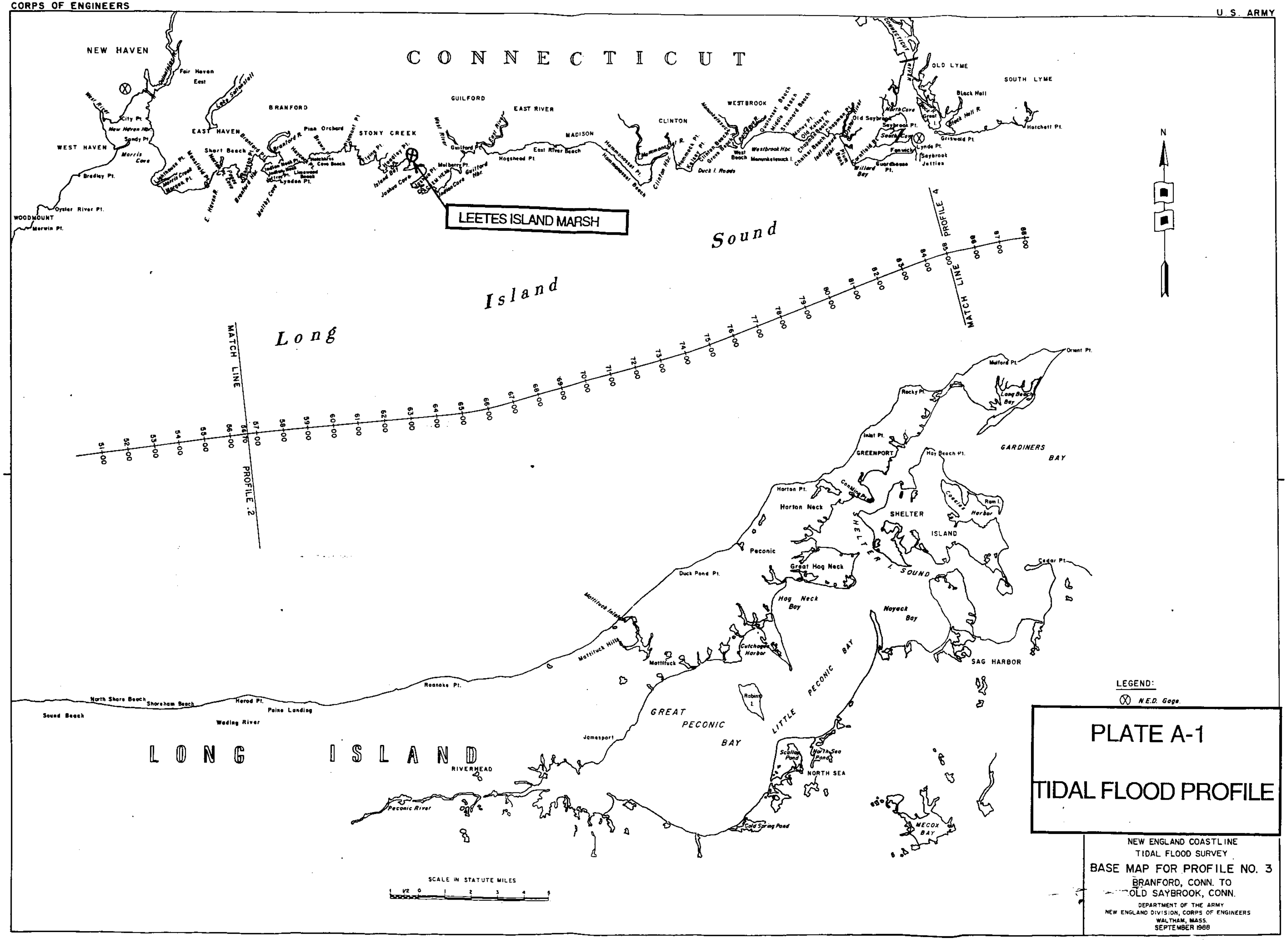


PLATE A-1

TIDAL FLOOD PROFILE

NEW ENGLAND COASTLINE
TIDAL FLOOD SURVEY
BASE MAP FOR PROFILE NO. 3
BRANFORD, CONN. TO
OLD SAYBROOK, CONN.
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.
SEPTEMBER 1988

CORPS OF ENGINEERS

U. S. ARMY

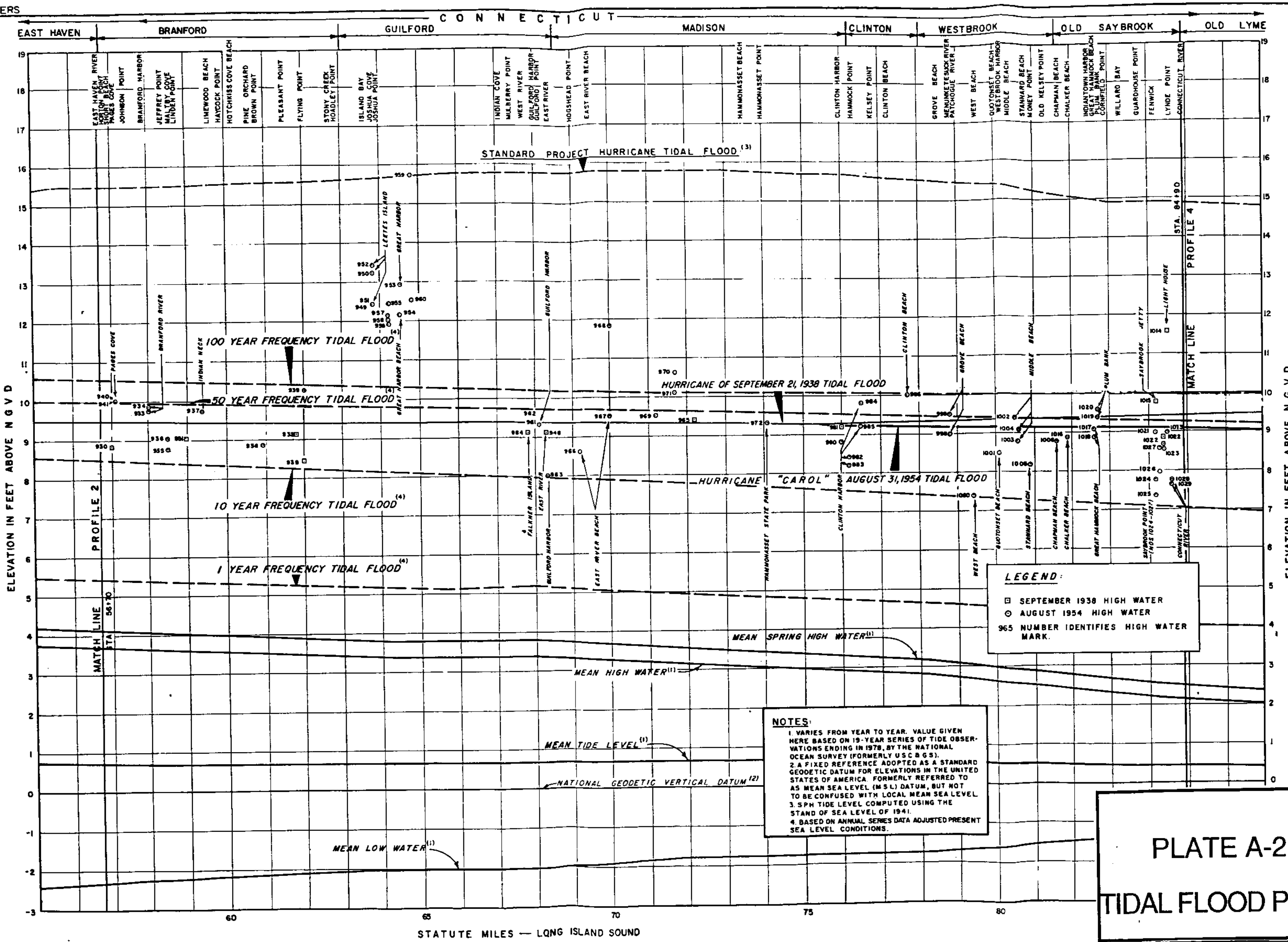


PLATE A-2

TIDAL FLOOD PROFILE

NEW ENGLAND COASTLINE
TIDAL FLOOD SURVEY

TIDAL FLOOD PROFILE NO. 3

BRANFORD, CONN., TO
OLD SAYBROOK, CONN.

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.
SEPTEMBER 1988

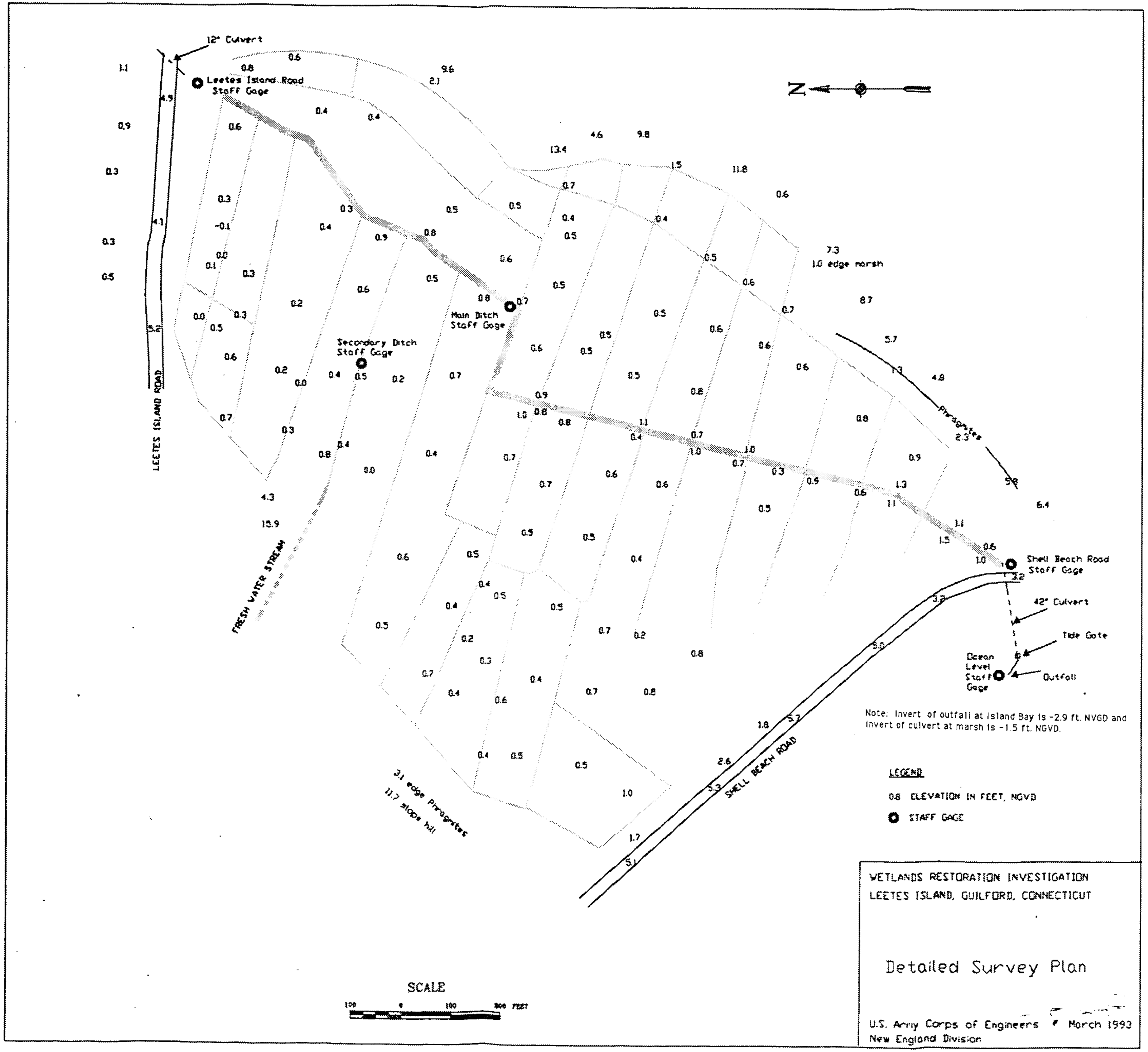

12" Culvert
Leetes Island Road Staff Gage
LEETES ISLAND ROAD
Secondary Ditch Staff Gage
Main Ditch Staff Gage
1.0 edge marsh
Phragmites
FRESH WATER STREAM
3.1 edge Phragmites
11.7 slope hill
Shell Beach Road Staff Gage
42" Culvert
Tide Gate
Ocean Level Staff Gage
Outfall
SHELL BEACH ROAD
Note: Invert of outfall at Island Bay is -2.9 ft. NVGD and invert of culvert at marsh is -1.5 ft. NGVD.
LEGEND
0.8 ELEVATION IN FEET, NGVD
STAFF GAGE
SCALE
100 0 100 200 FEET
WETLANDS RESTORATION INVESTIGATION
LEETES ISLAND, GUILFORD, CONNECTICUT
Detailed Survey Plan
U.S. Army Corps of Engineers March 1993
New England Division

PLATE A-3

LEETES ISLAND
TIDAL MEASUREMENTS
MARCH 19, 1992

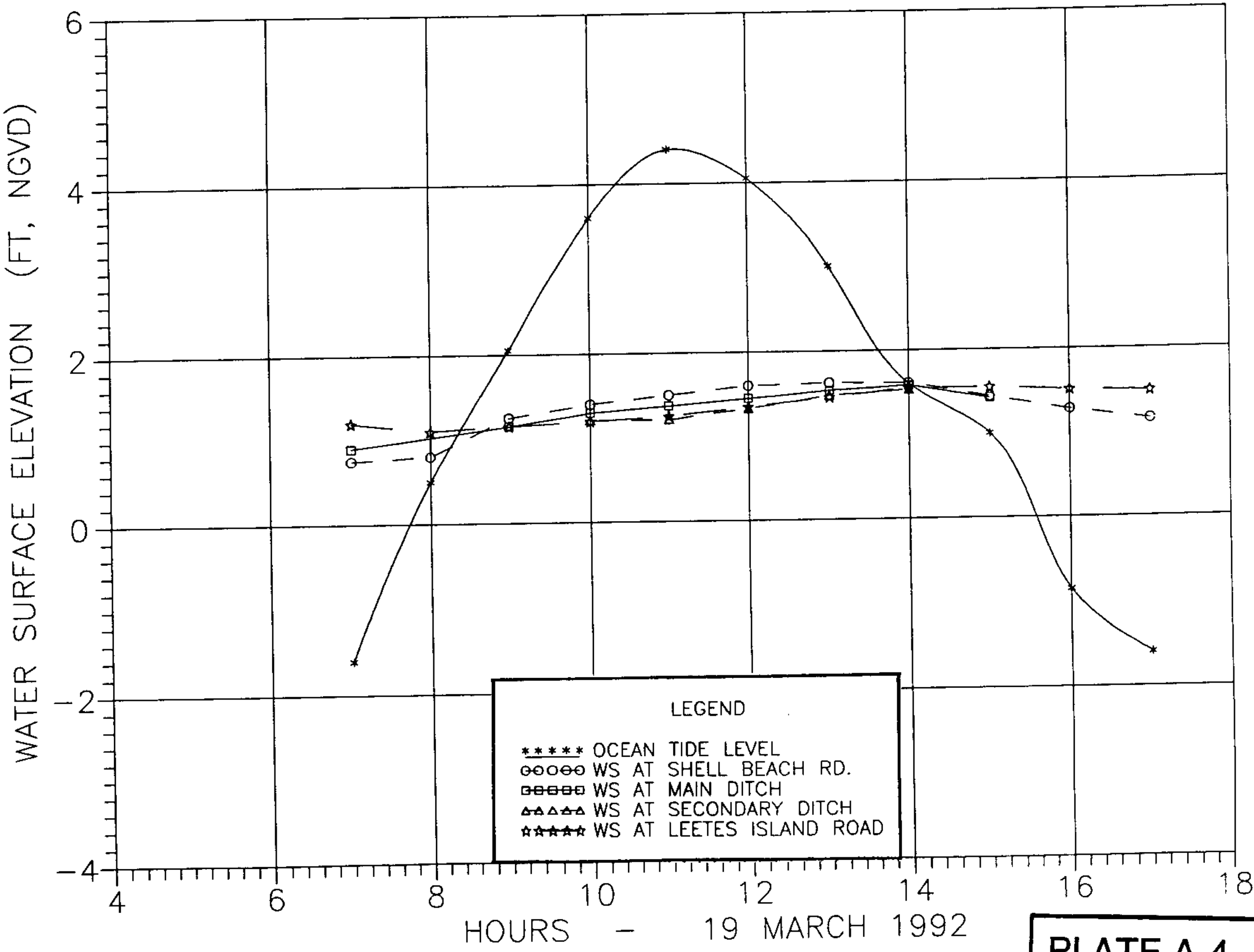


PLATE A-4

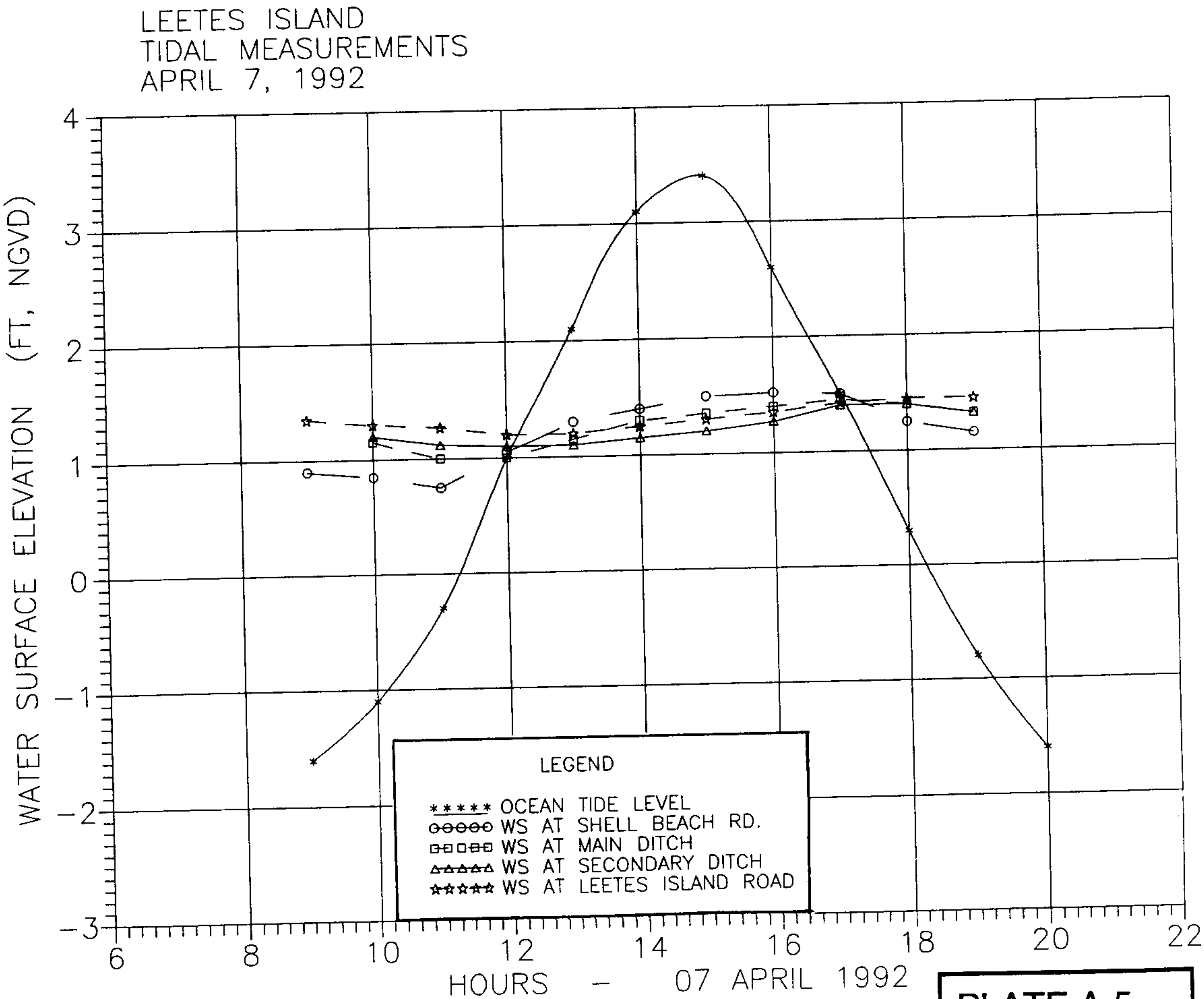

LEETES ISLAND
TIDAL MEASUREMENTS
APRIL 7, 1992
WATER SURFACE ELEVATION (FT, NGVD)
4
3
2
1
0
-1
-2
-3
6
8
10
12
14
16
18
20
22
HOURS - 07 APRIL 1992
LEGEND
OCEAN TIDE LEVEL
WS AT SHELL BEACH RD.
WS AT MAIN DITCH
WS AT SECONDARY DITCH
WS AT LEETES ISLAND ROAD

PLATE A-5

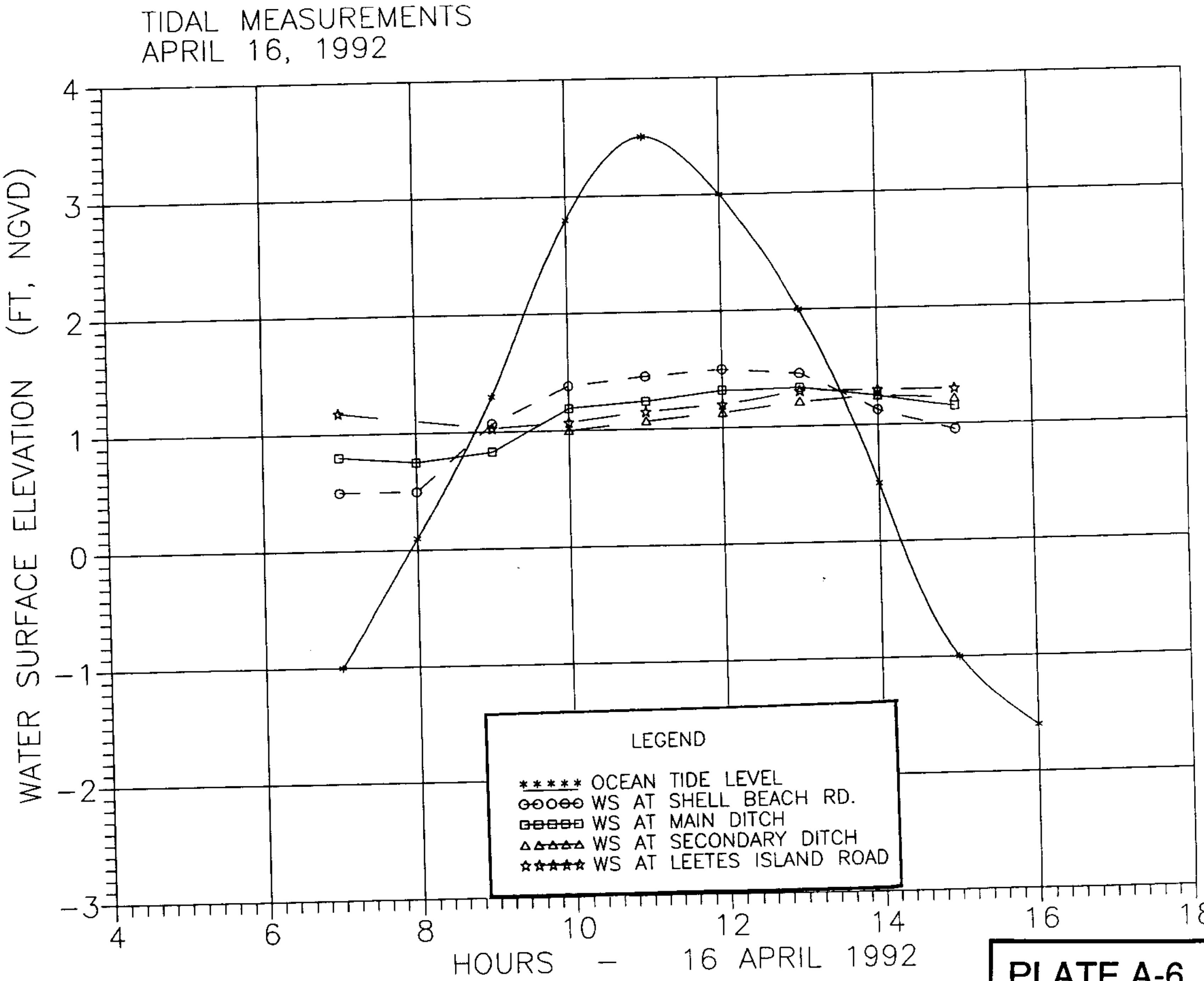

TIDAL MEASUREMENTS
APRIL 16, 1992
WATER SURFACE ELEVATION (FT, NGVD)
4
3
2
1
0
−1
−2
−3
4
6
8
10
12
14
16
18
HOURS — 16 APRIL 1992
LEGEND
OCEAN TIDE LEVEL
WS AT SHELL BEACH RD.
WS AT MAIN DITCH
WS AT SECONDARY DITCH
WS AT LEETES ISLAND ROAD

PLATE A-6

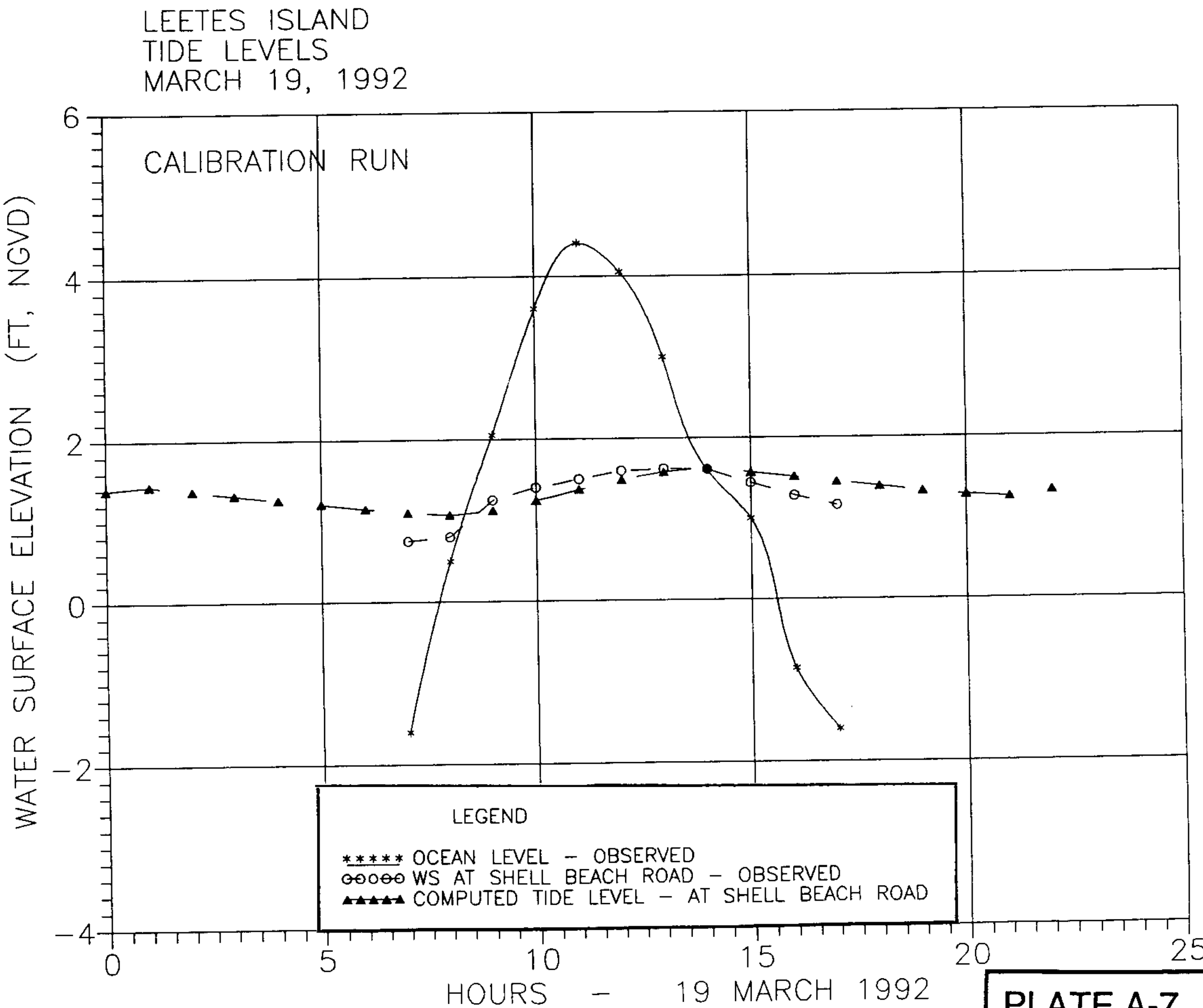

LEETES ISLAND
TIDE LEVELS
MARCH 19, 1992
CALIBRATION RUN
WATER SURFACE ELEVATION (FT, NGVD)
6
4
2
0
-2
-4
0
5
10
15
20
25
HOURS - 19 MARCH 1992
LEGEND
***** OCEAN LEVEL - OBSERVED
ooooo WS AT SHELL BEACH ROAD - OBSERVED
▲▲▲▲▲ COMPUTED TIDE LEVEL - AT SHELL BEACH ROAD

PLATE A-7

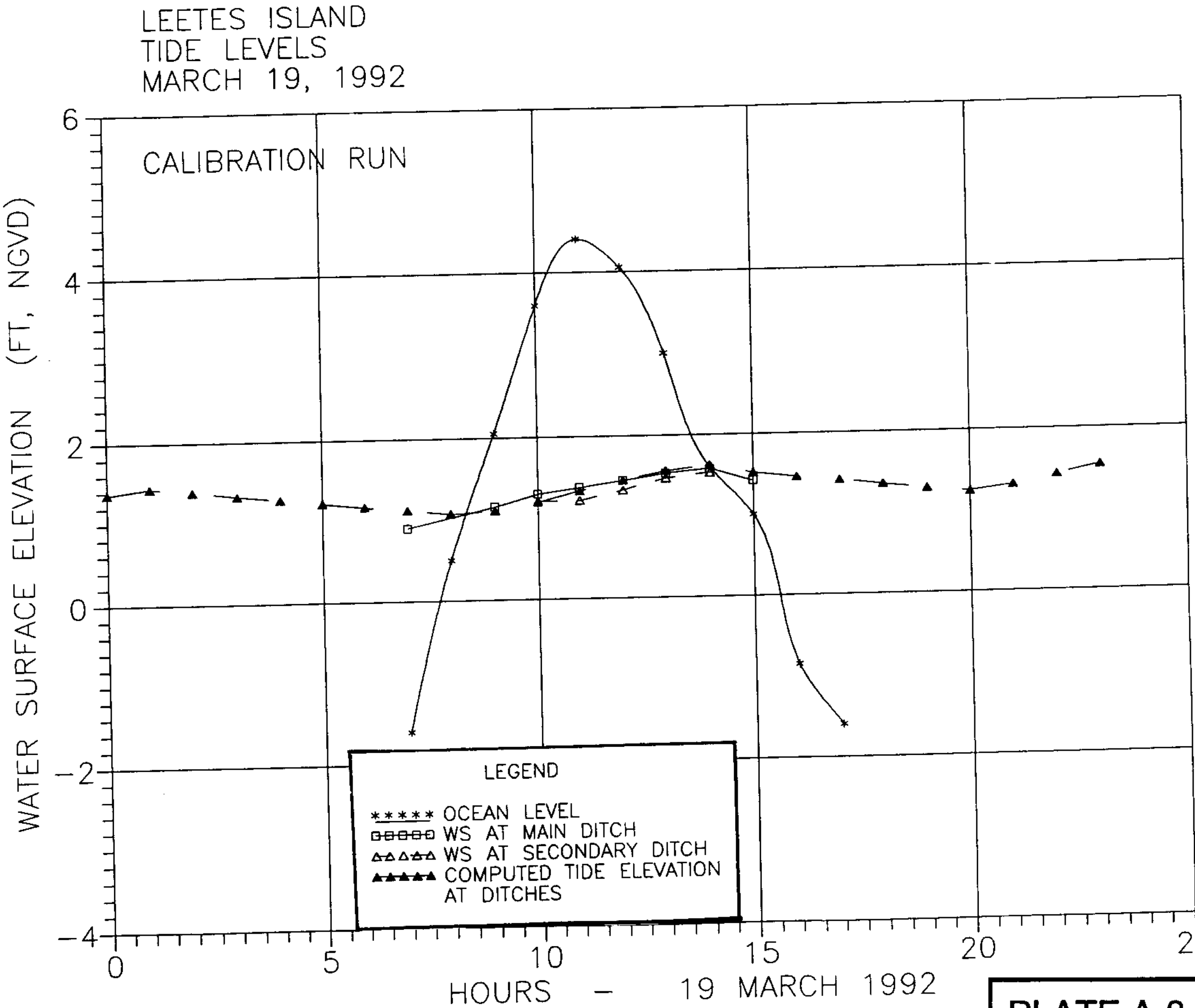
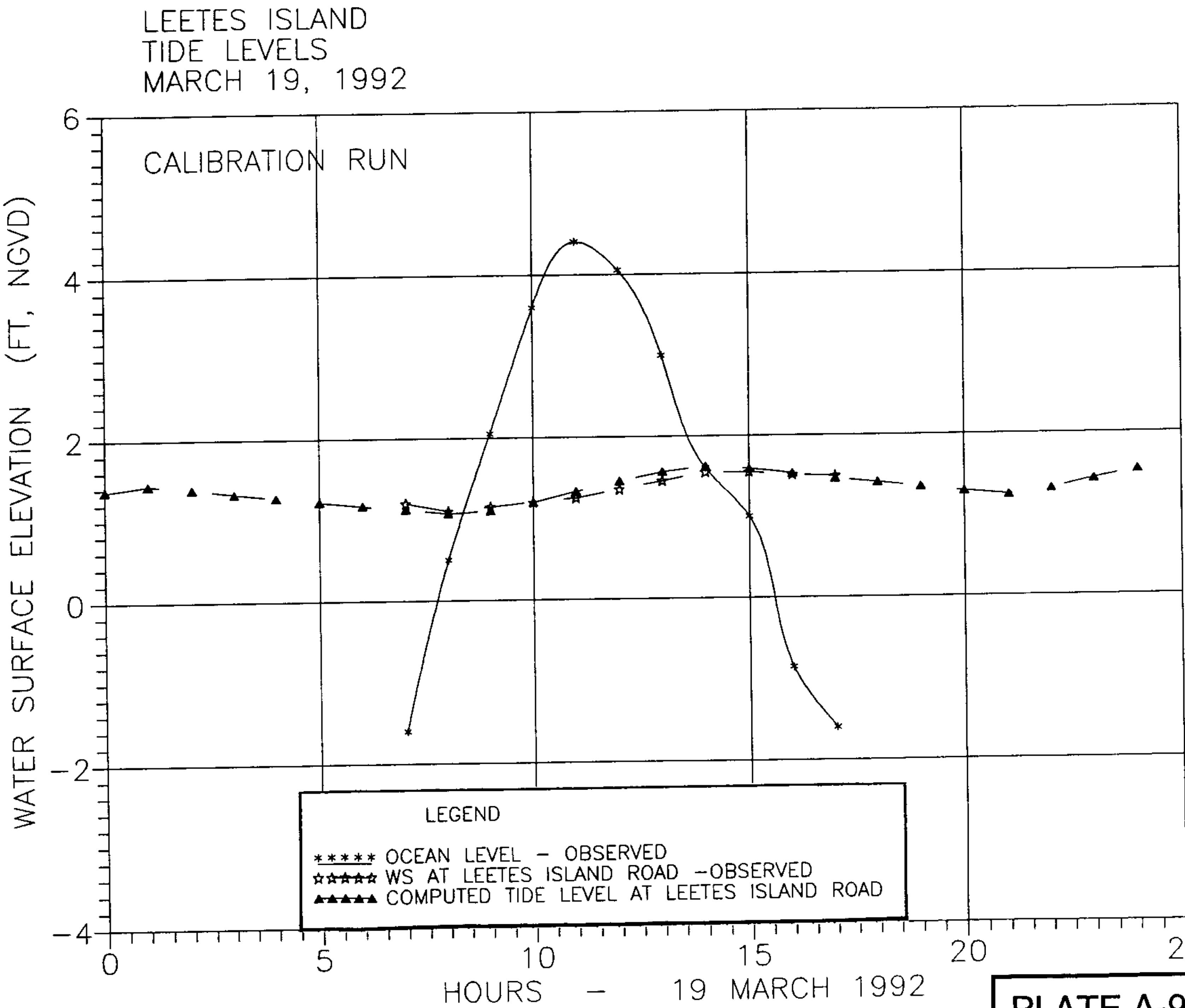

LEETES ISLAND
TIDE LEVELS
MARCH 19, 1992
CALIBRATION RUN
WATER SURFACE ELEVATION (FT, NGVD)
6
4
2
0
-2
-4
0
5
10
15
20
25
HOURS - 19 MARCH 1992
LEGEND
OCEAN LEVEL
WS AT MAIN DITCH
WS AT SECONDARY DITCH
COMPUTED TIDE ELEVATION AT DITCHES

PLATE A-8



LEETES ISLAND
TIDE LEVELS
MARCH 19, 1992
CALIBRATION RUN
WATER SURFACE ELEVATION (FT, NGVD)
6
4
2
0
-2
-4
0
5
10
15
20
25
HOURS - 19 MARCH 1992
LEGEND
OCEAN LEVEL - OBSERVED
WS AT LEETES ISLAND ROAD -OBSERVED
COMPUTED TIDE LEVEL AT LEETES ISLAND ROAD

PLATE A-9

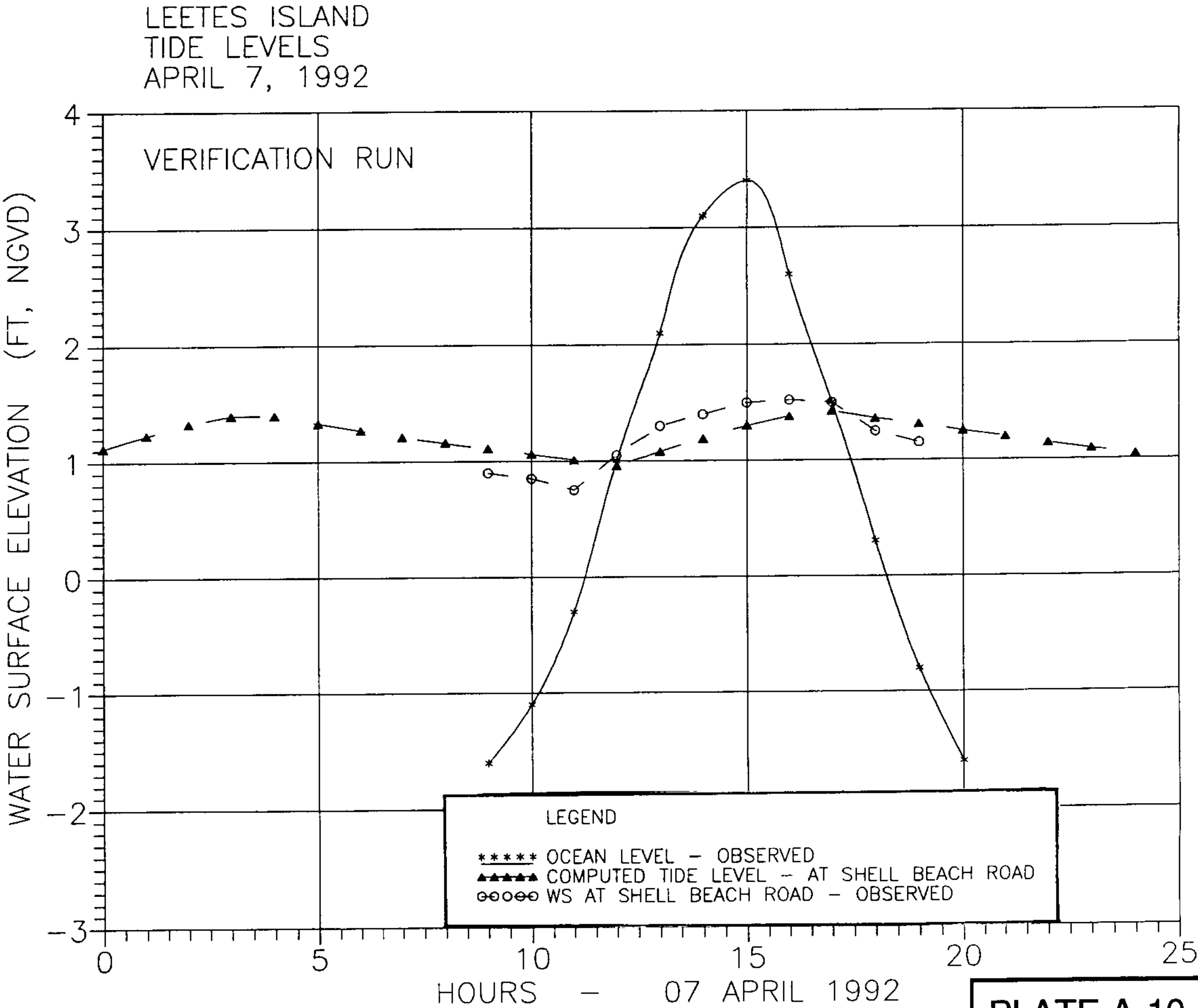
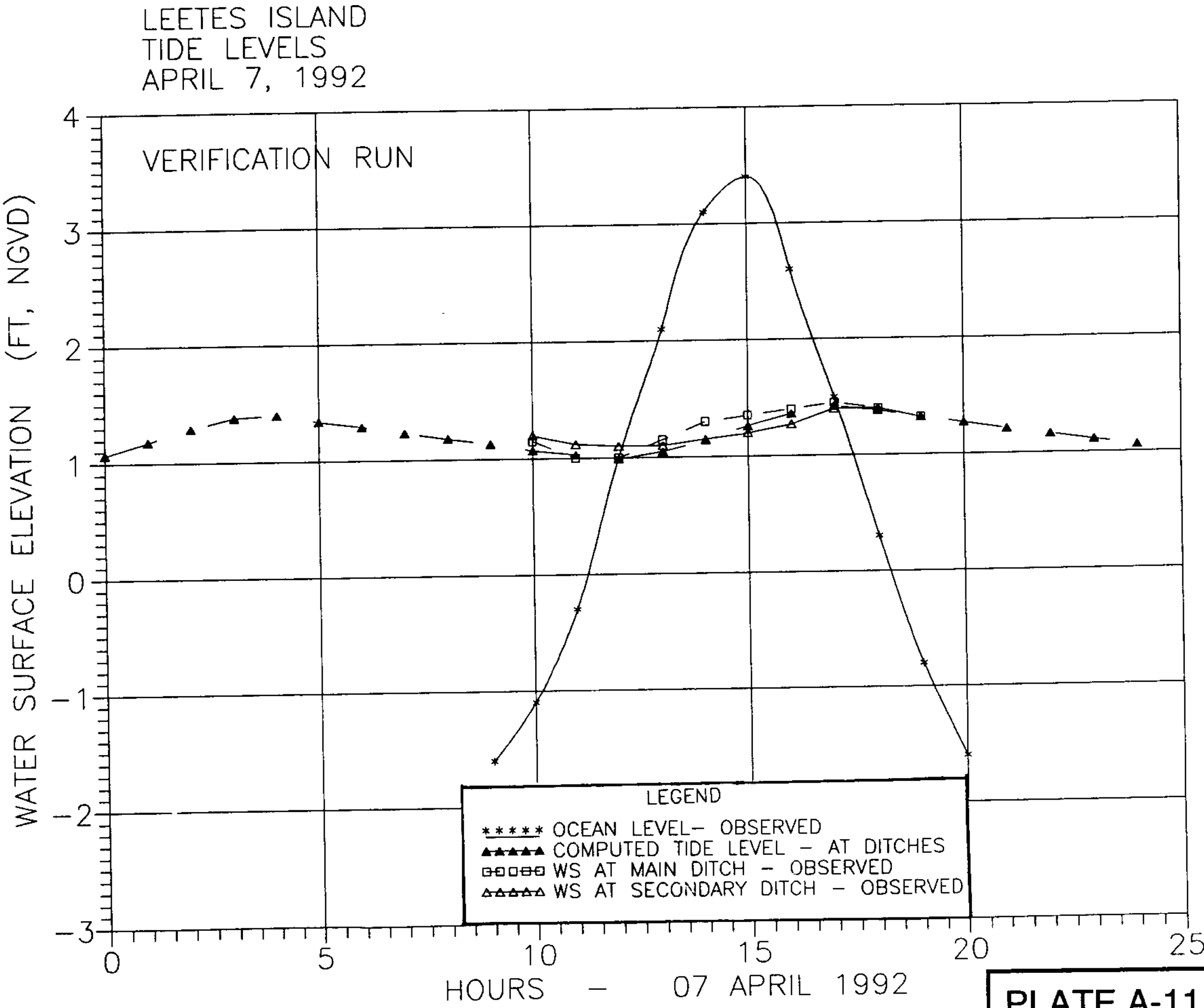

LEETES ISLAND
TIDE LEVELS
APRIL 7, 1992
VERIFICATION RUN
WATER SURFACE ELEVATION (FT, NGVD)
HOURS - 07 APRIL 1992
LEGEND
OCEAN LEVEL - OBSERVED
COMPUTED TIDE LEVEL - AT SHELL BEACH ROAD
WS AT SHELL BEACH ROAD - OBSERVED
4
3
2
1
0
-1
-2
-3
0
5
10
15
20
25

PLATE A-10



LEETES ISLAND
TIDE LEVELS
APRIL 7, 1992
VERIFICATION RUN
WATER SURFACE ELEVATION (FT, NGVD)
4
3
2
1
0
-1
-2
-3
0
5
10
15
20
25
HOURS - 07 APRIL 1992
LEGEND
OCEAN LEVEL- OBSERVED
COMPUTED TIDE LEVEL - AT DITCHES
WS AT MAIN DITCH - OBSERVED
WS AT SECONDARY DITCH - OBSERVED

PLATE A-11

LEETES ISLAND
TIDE LEVELS
APRIL 7, 1992

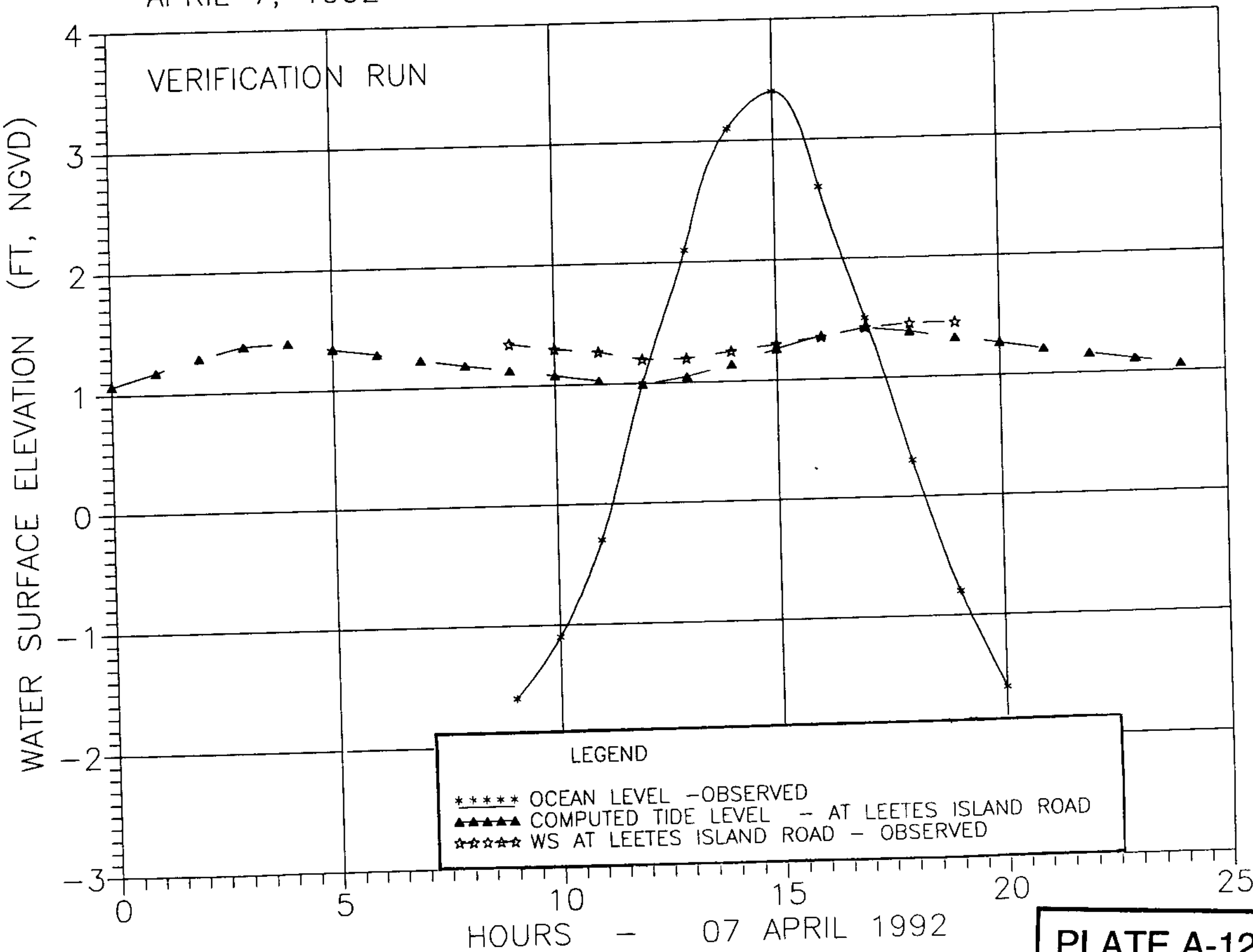


PLATE A-12

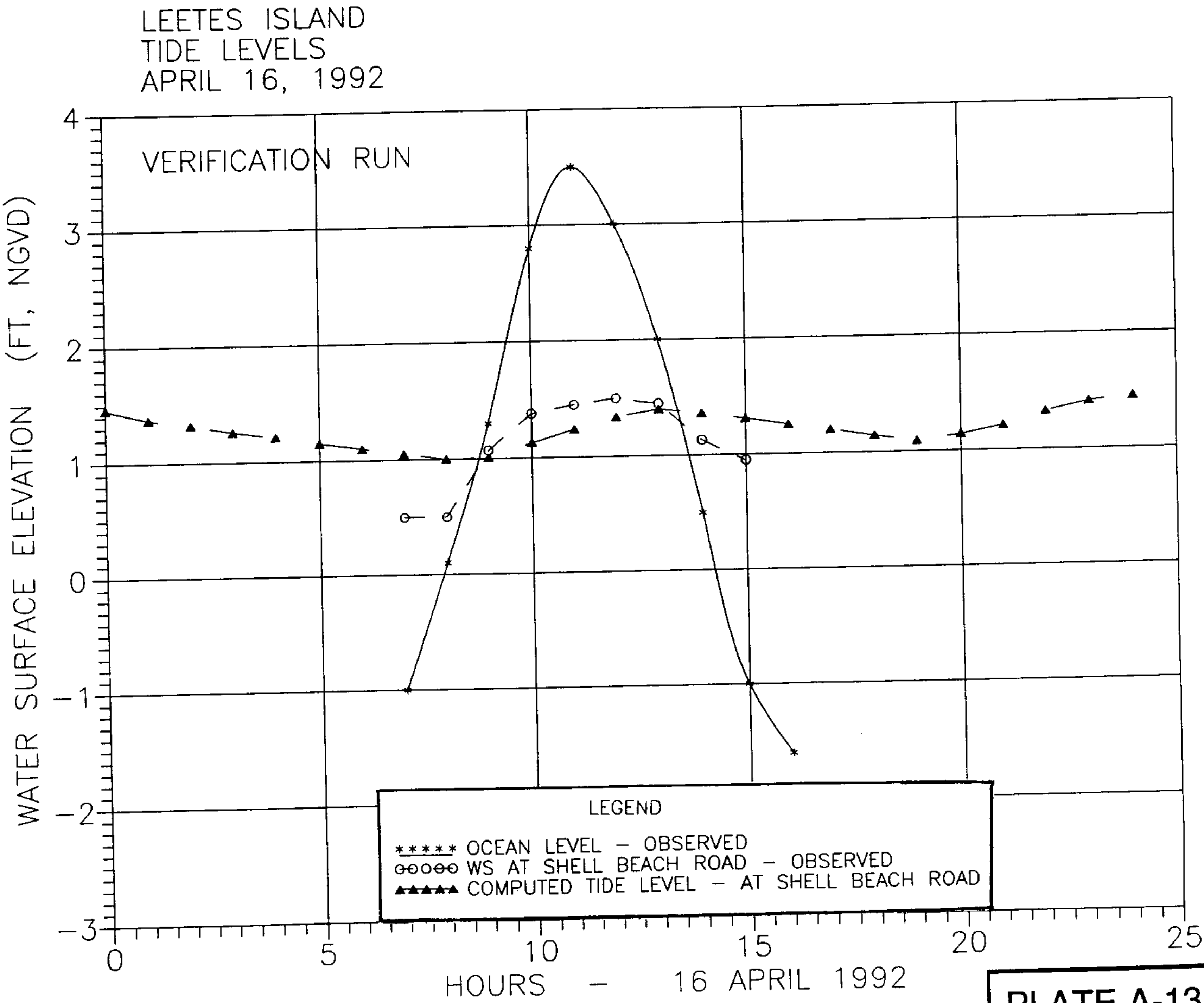

LEETES ISLAND
TIDE LEVELS
APRIL 16, 1992
VERIFICATION RUN
WATER SURFACE ELEVATION (FT, NGVD)
4
3
2
1
0
-1
-2
-3
0
5
10
15
20
25
HOURS - 16 APRIL 1992
LEGEND
OCEAN LEVEL - OBSERVED
WS AT SHELL BEACH ROAD - OBSERVED
COMPUTED TIDE LEVEL - AT SHELL BEACH ROAD

PLATE A-13

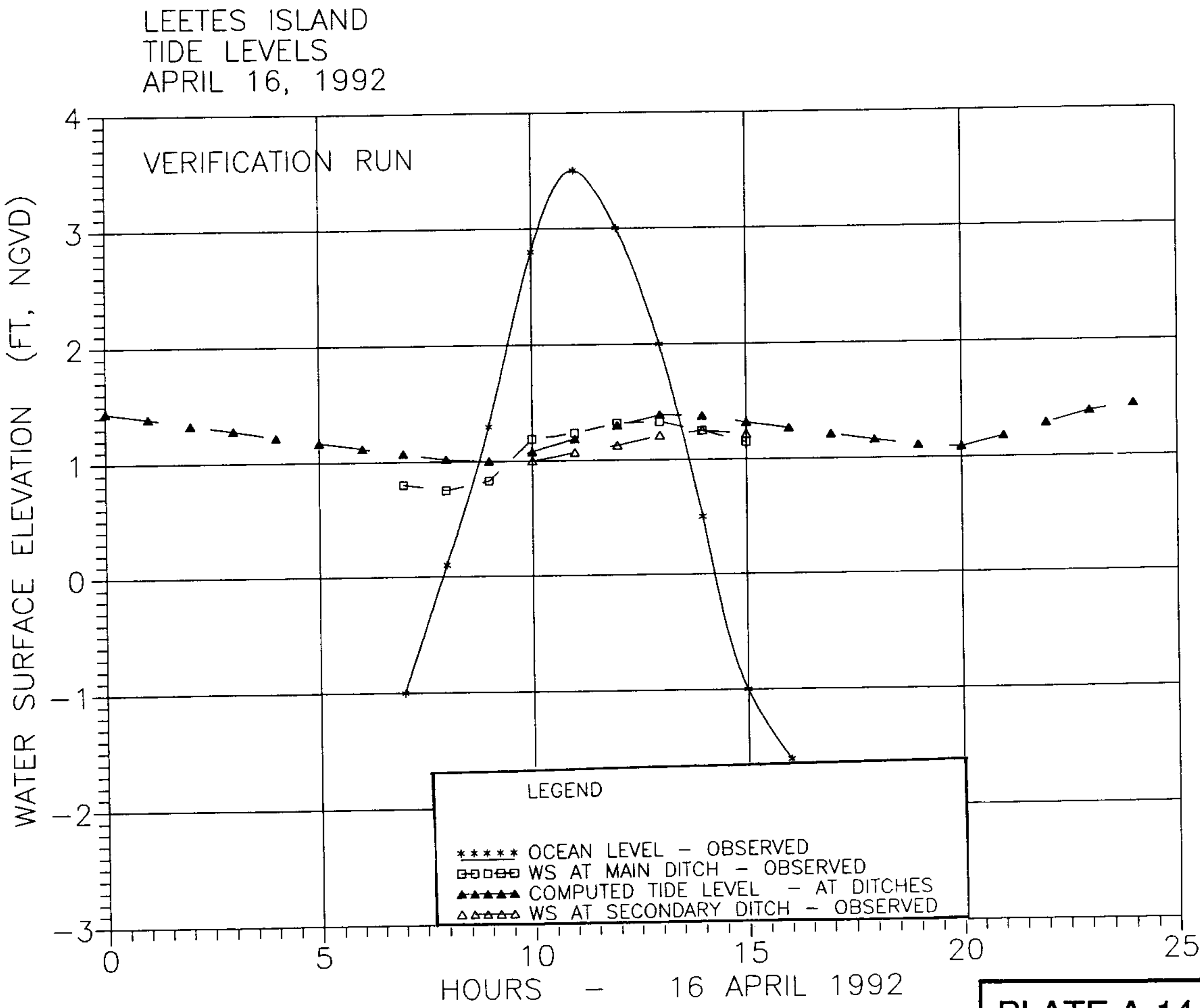

LEETES ISLAND
TIDE LEVELS
APRIL 16, 1992
VERIFICATION RUN
WATER SURFACE ELEVATION (FT, NGVD)
HOURS - 16 APRIL 1992
LEGEND
OCEAN LEVEL - OBSERVED
WS AT MAIN DITCH - OBSERVED
COMPUTED TIDE LEVEL - AT DITCHES
WS AT SECONDARY DITCH - OBSERVED
4
3
2
1
0
-1
-2
-3
0
5
10
15
20
25

PLATE A-14

LEETES ISLAND
TIDE LEVELS
APRIL 16, 1992

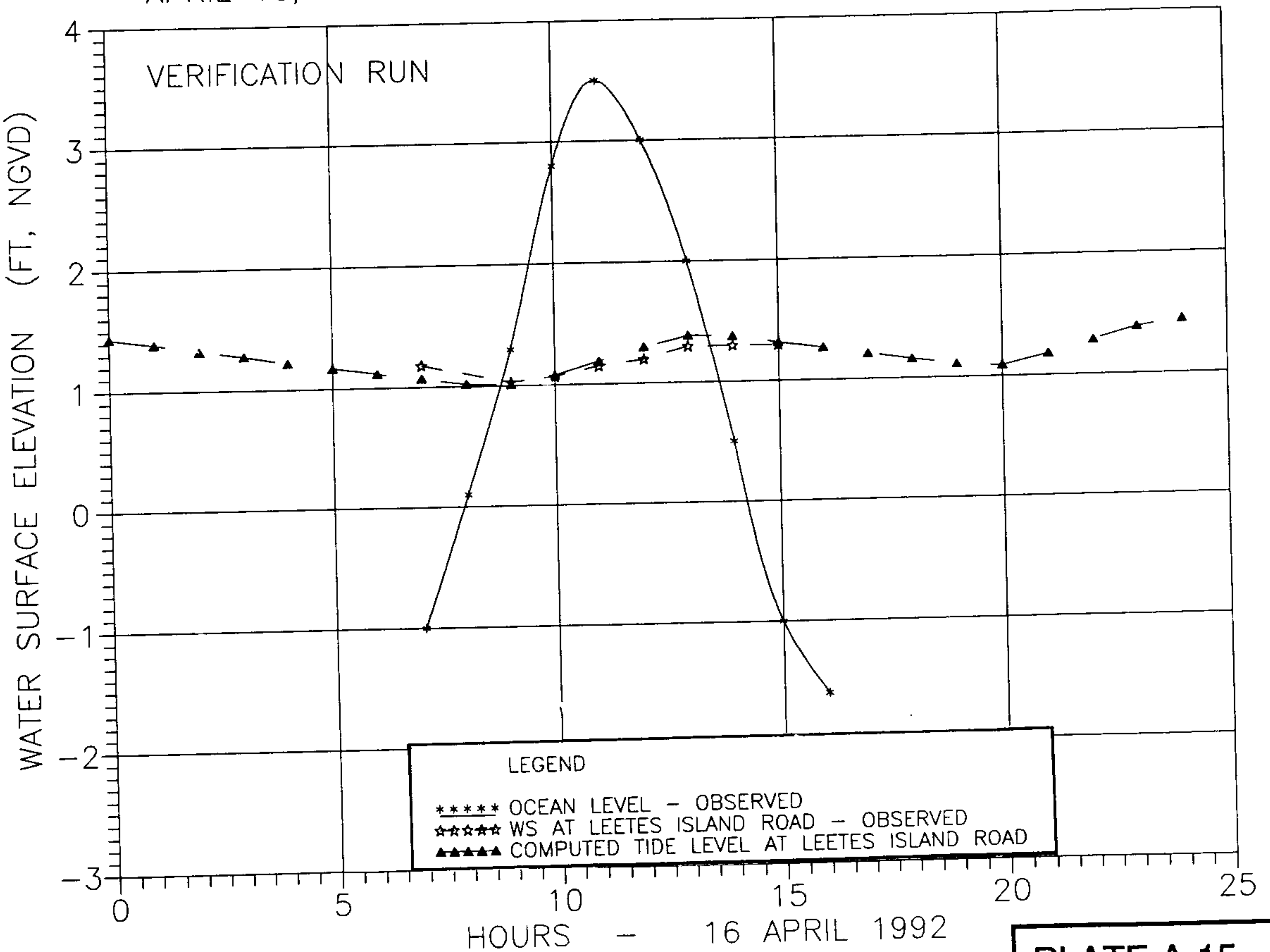


PLATE A-15

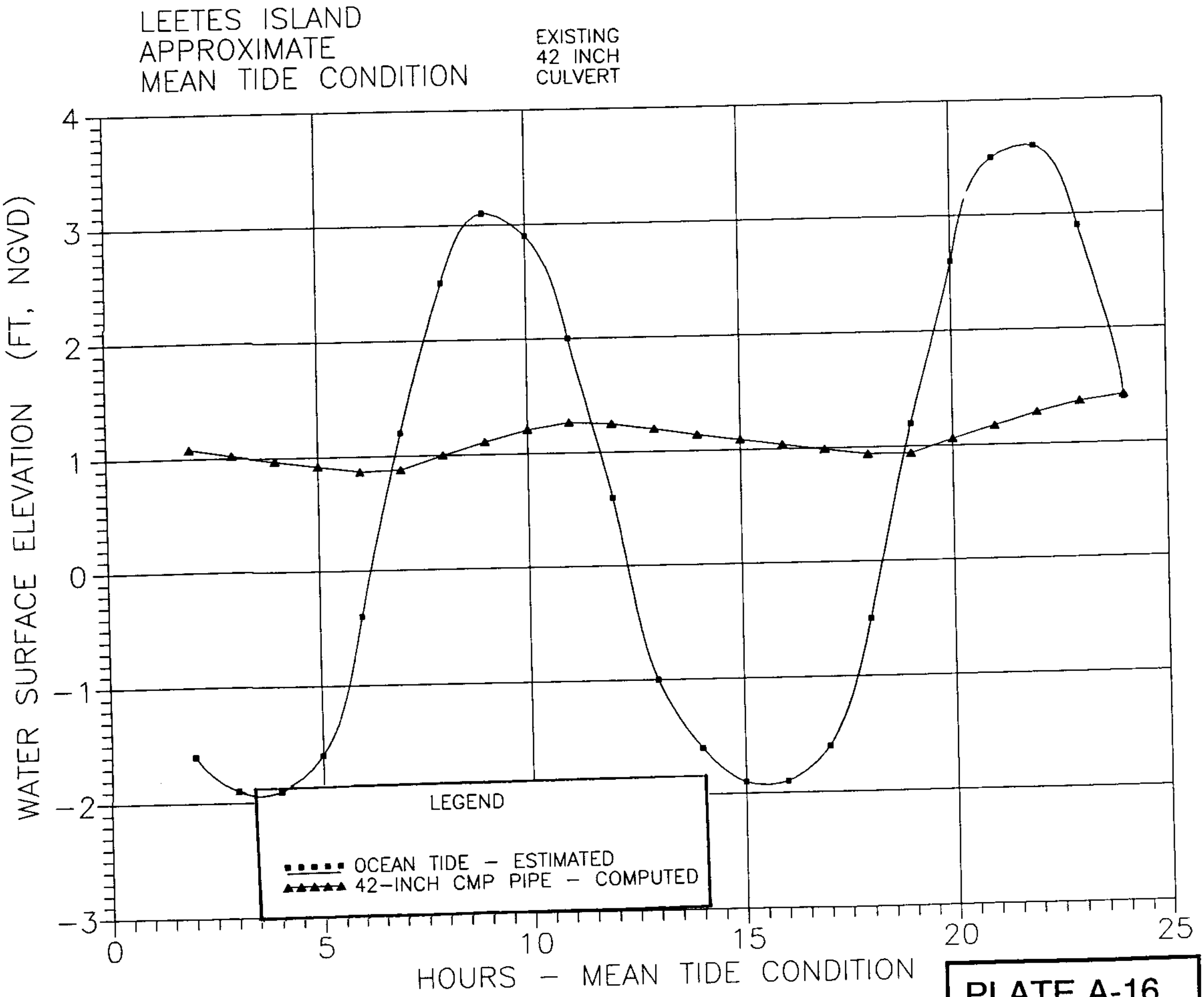
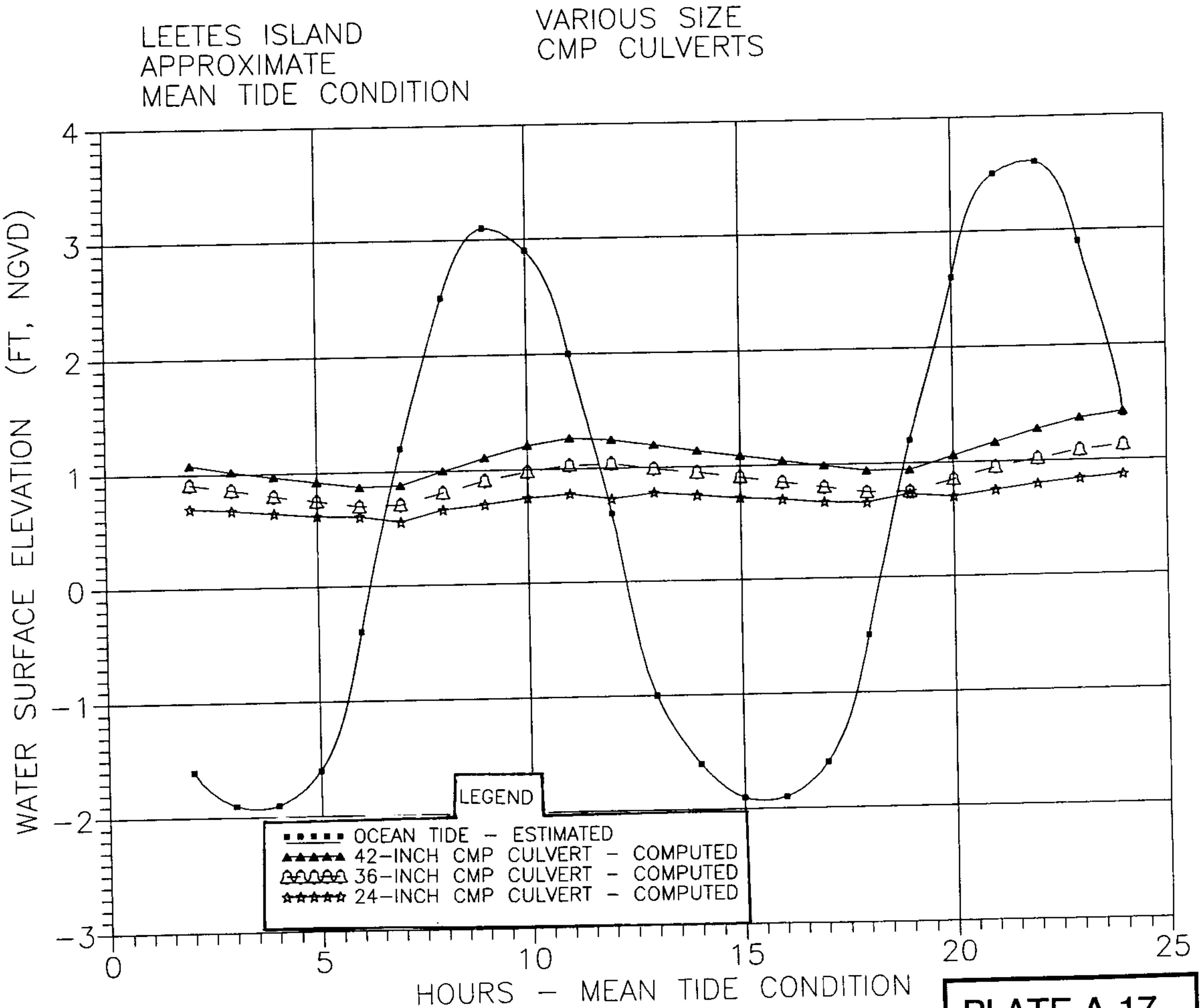
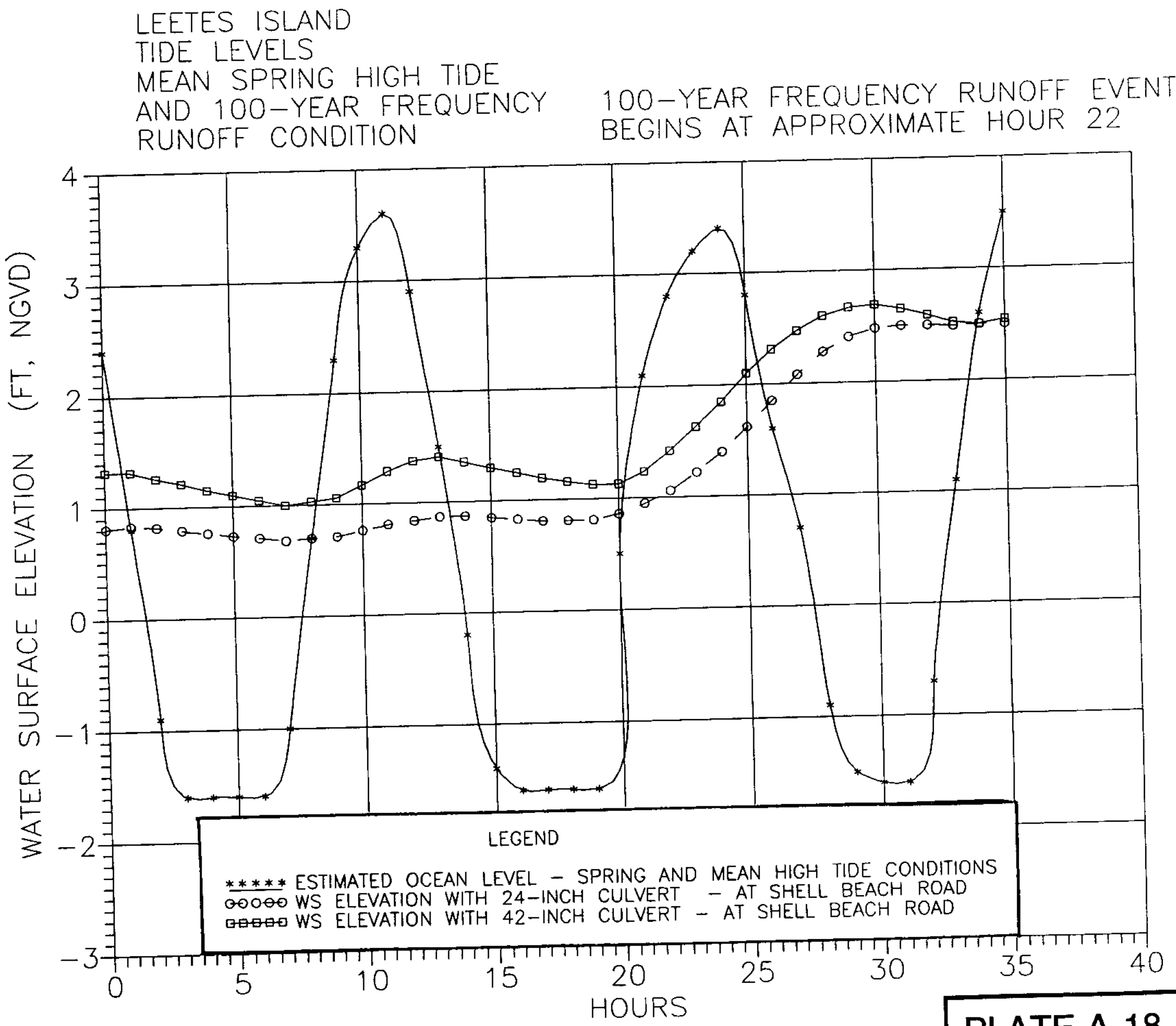

LEETES ISLAND
APPROXIMATE
MEAN TIDE CONDITION
EXISTING
42 INCH
CULVERT
WATER SURFACE ELEVATION (FT, NGVD)
4
3
2
1
0
−1
−2
−3
0
5
10
15
20
25
HOURS – MEAN TIDE CONDITION
LEGEND
OCEAN TIDE – ESTIMATED
42-INCH CMP PIPE – COMPUTED

PLATE A-16



LEETES ISLAND
APPROXIMATE
MEAN TIDE CONDITION
VARIOUS SIZE
CMP CULVERTS
WATER SURFACE ELEVATION (FT, NGVD)
HOURS – MEAN TIDE CONDITION
4
3
2
1
0
−1
−2
−3
0
5
10
15
20
25
LEGEND
OCEAN TIDE – ESTIMATED
42-INCH CMP CULVERT – COMPUTED
36-INCH CMP CULVERT – COMPUTED
24-INCH CMP CULVERT – COMPUTED

PLATE A-17



LEETES ISLAND
TIDE LEVELS
MEAN SPRING HIGH TIDE
AND 100-YEAR FREQUENCY
RUNOFF CONDITION
100-YEAR FREQUENCY RUNOFF EVENT
BEGINS AT APPROXIMATE HOUR 22
WATER SURFACE ELEVATION (FT, NGVD)
4
3
2
1
0
-1
-2
-3
0
5
10
15
20
25
30
35
40
HOURS
LEGEND
***** ESTIMATED OCEAN LEVEL - SPRING AND MEAN HIGH TIDE CONDITIONS
WS ELEVATION WITH 24-INCH CULVERT - AT SHELL BEACH ROAD
WS ELEVATION WITH 42-INCH CULVERT - AT SHELL BEACH ROAD

PLATE A-18

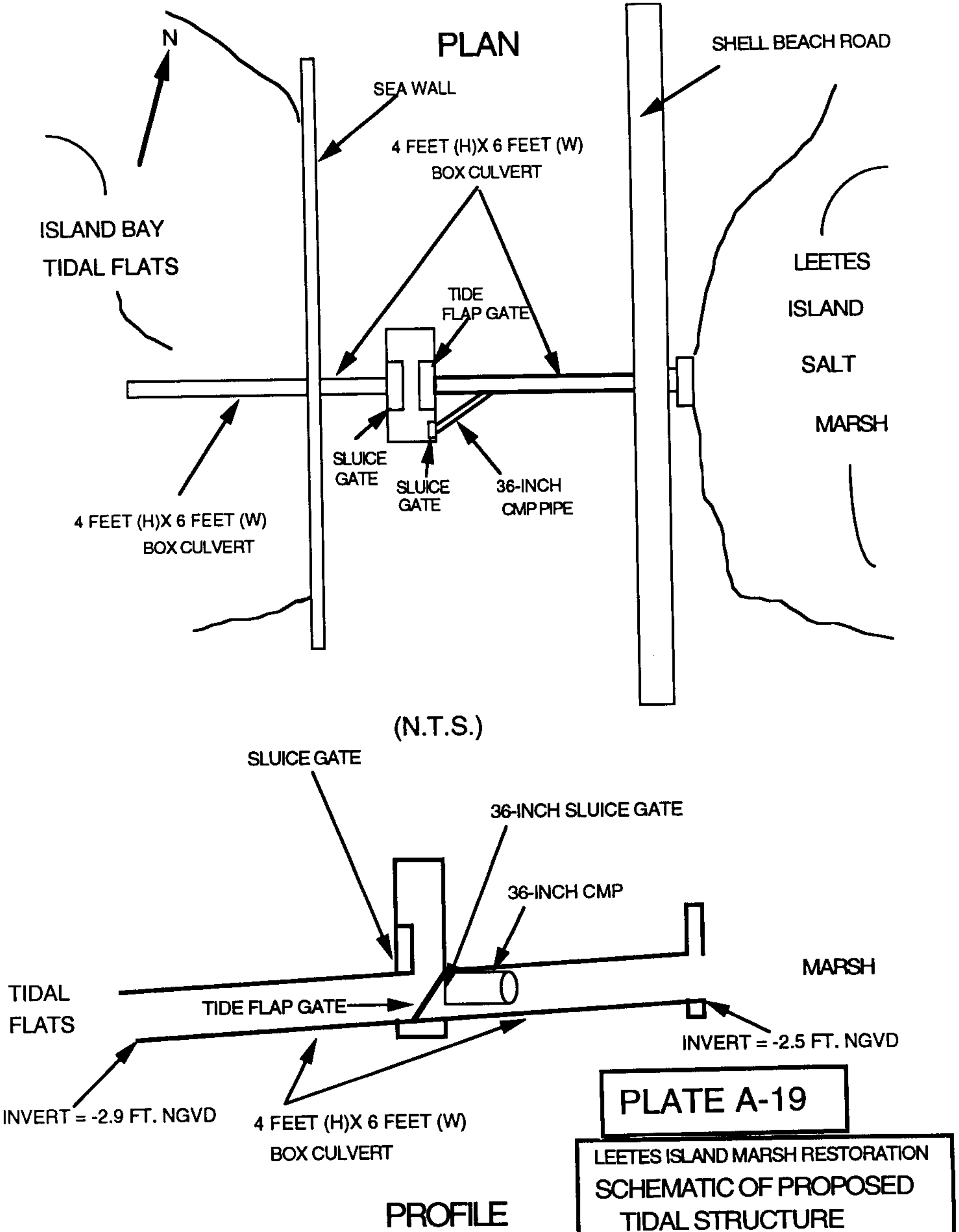


PLATE A-19

LEETES ISLAND MARSH RESTORATION
SCHEMATIC OF PROPOSED
TIDAL STRUCTURE
FEB 1993 HWQB

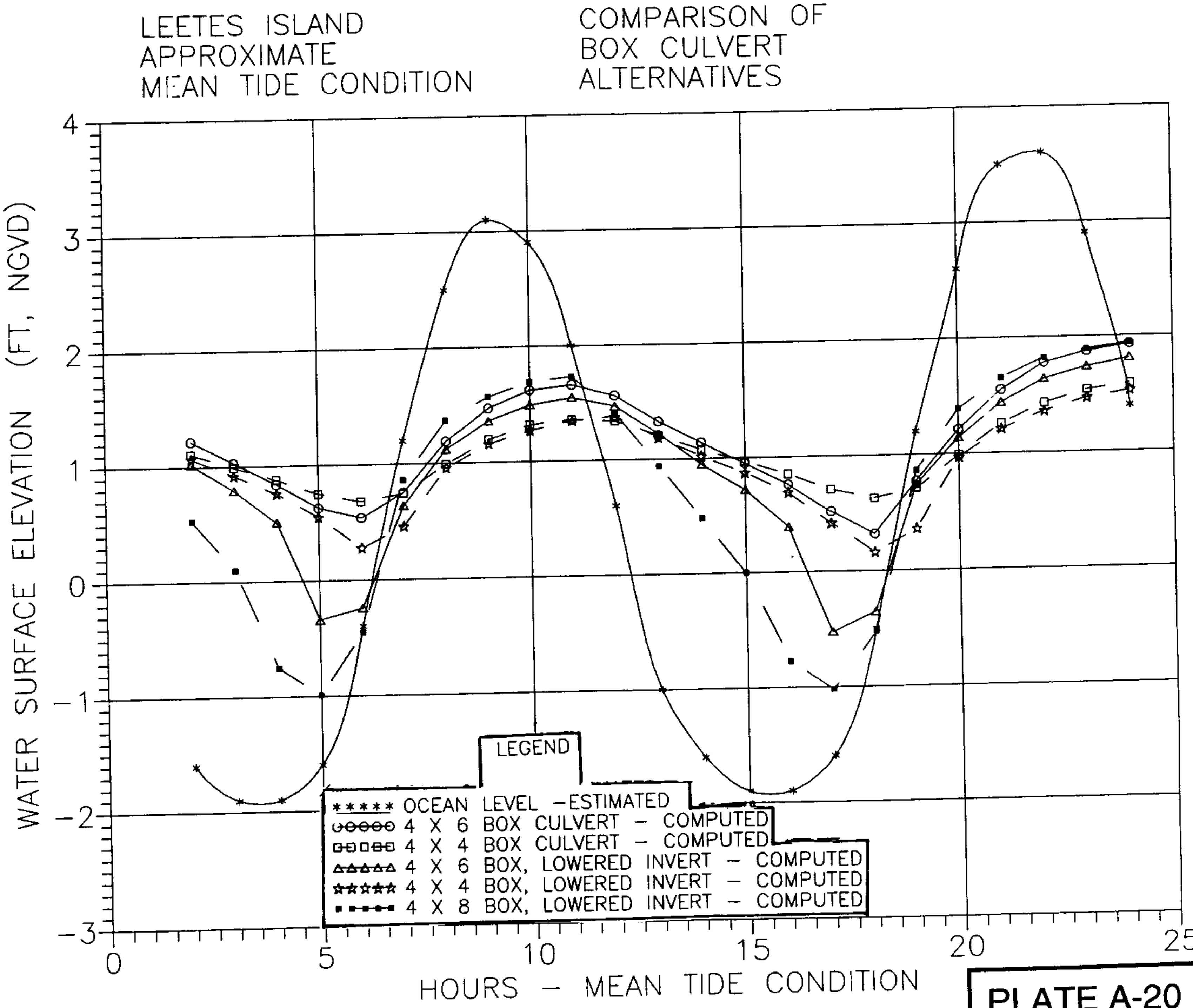

LEETES ISLAND
APPROXIMATE
MEAN TIDE CONDITION
COMPARISON OF
BOX CULVERT
ALTERNATIVES
WATER SURFACE ELEVATION (FT, NGVD)
HOURS - MEAN TIDE CONDITION
4
3
2
1
0
-1
-2
-3
0
5
10
15
20
25
LEGEND
OCEAN LEVEL -ESTIMATED
4 X 6 BOX CULVERT - COMPUTED
4 X 4 BOX CULVERT - COMPUTED
4 X 6 BOX, LOWERED INVERT - COMPUTED
4 X 4 BOX, LOWERED INVERT - COMPUTED
4 X 8 BOX, LOWERED INVERT - COMPUTED

PLATE A-20

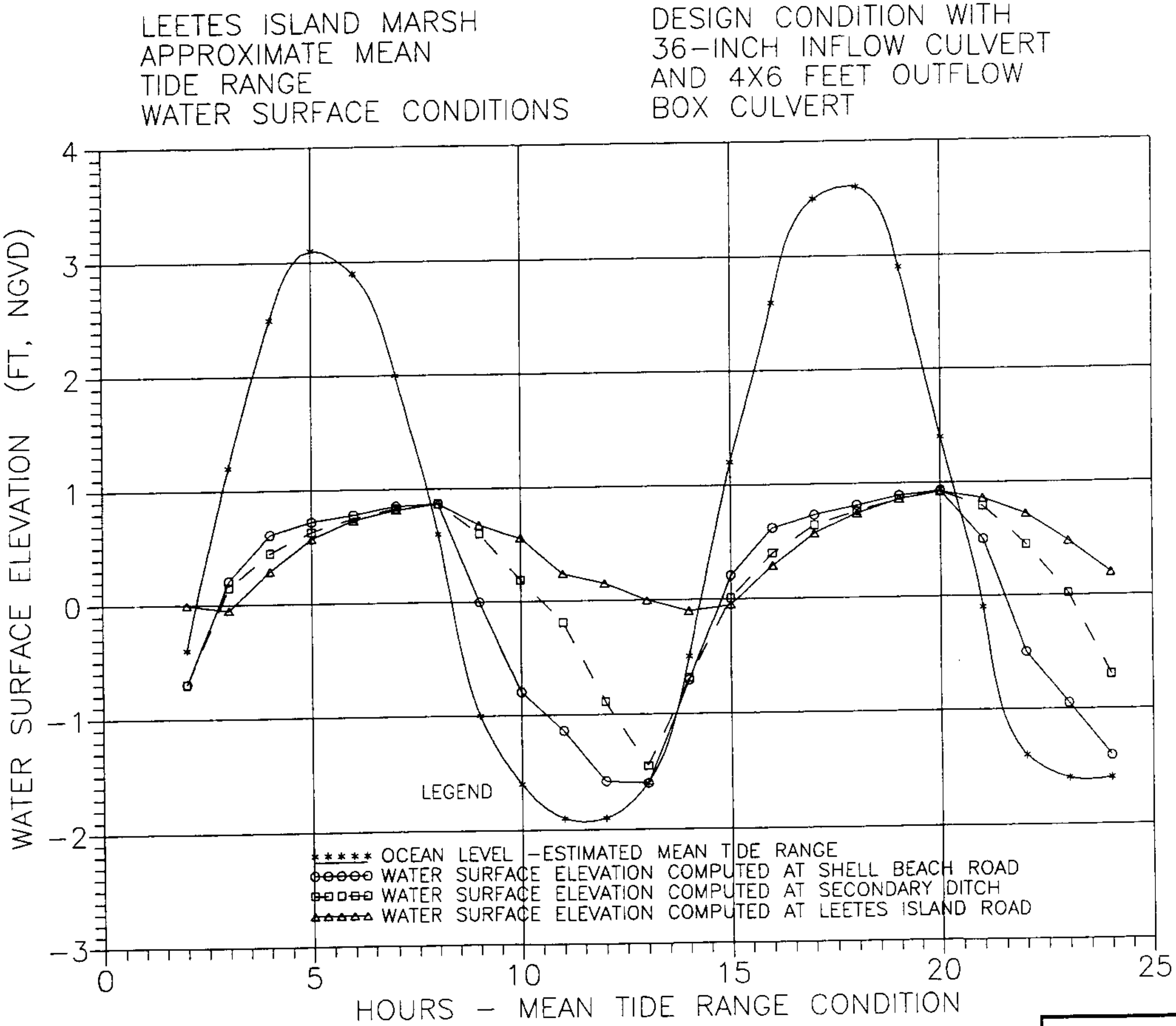

LEETES ISLAND MARSH
APPROXIMATE MEAN
TIDE RANGE
WATER SURFACE CONDITIONS
DESIGN CONDITION WITH
36-INCH INFLOW CULVERT
AND 4X6 FEET OUTFLOW
BOX CULVERT
WATER SURFACE ELEVATION (FT, NGVD)
HOURS - MEAN TIDE RANGE CONDITION
LEGEND
OCEAN LEVEL -ESTIMATED MEAN TIDE RANGE
WATER SURFACE ELEVATION COMPUTED AT SHELL BEACH ROAD
WATER SURFACE ELEVATION COMPUTED AT SECONDARY DITCH
WATER SURFACE ELEVATION COMPUTED AT LEETES ISLAND ROAD
4
3
2
1
0
-1
-2
-3
0
5
10
15
20
25

PLATE A-20A

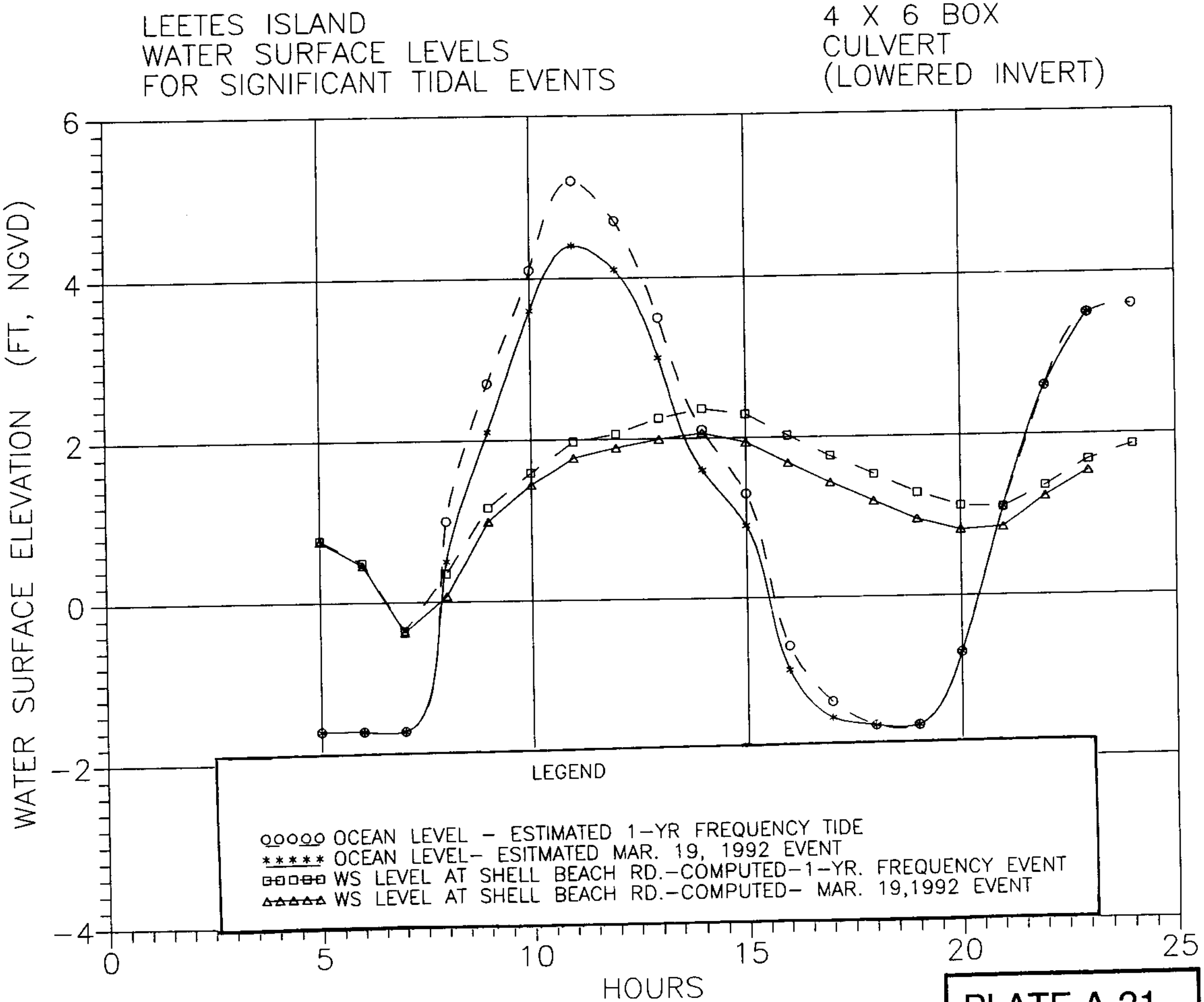

LEETES ISLAND
WATER SURFACE LEVELS
FOR SIGNIFICANT TIDAL EVENTS
4 X 6 BOX
CULVERT
(LOWERED INVERT)
WATER SURFACE ELEVATION (FT, NGVD)
6
4
2
0
−2
−4
0
5
10
15
20
25
HOURS
LEGEND
OCEAN LEVEL - ESTIMATED 1-YR FREQUENCY TIDE
OCEAN LEVEL- ESITMATED MAR. 19, 1992 EVENT
WS LEVEL AT SHELL BEACH RD.-COMPUTED-1-YR. FREQUENCY EVENT
WS LEVEL AT SHELL BEACH RD.-COMPUTED- MAR. 19,1992 EVENT

PLATE A-21

APPENDIX B

ECOLOGICAL EVALUATIONS

APPENDIX B

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. Vegetation and Ecology of the Leetes Island Marsh

A. General

The Leetes Island marsh presently supports a high salt marsh plant community. It differs from the typical high marsh pattern as an apparent result of the combined effects of tidal restriction and regular salt hay mowing. The dominant plant species in a typical New England high salt marsh is salt meadow grass (Spartina patens) with spike grass (Distichlis spicata), black grass (Juncus gerardi), and the short form of salt marsh cordgrass (Spartina alterniflora) locally dominant but less abundant overall.

At Leetes Island, the tide gate connecting the marsh to Long Island Sound is closed during the summer to allow mowing of salt hay by the owner. This limits tidal flooding of the marsh during the growing season. Normally this would result in a change in plant community type to species characteristic of less saline conditions, but at the Leetes Island regular marsh mowing and possibly areas of locally high soil water salinity are apparently deterring the encroachment of a less saline plant community.

Roman et. al. (1984)[1] suggested that mowing for salt hay at the Leete [Leetes Island] Marsh is deterring the encroachment of common reed (Phragmites australis) into the spike grass dominated marsh. They suggest that, "if mowing were discontinued, Phragmites currently established around the marsh periphery and along ditches would probably rapidly spread and dominate the system." The presence of common reed, or Phragmites, on interior portions of the marsh and in fairly wide bands along the edges of ditches suggests that the present level of tidal exchange is not sufficient to maintain the observed condition of high marsh vegetation. The presence of common reed is most likely due to the difficulty involved in operating the haying equipment near ditches as opposed to the levee effect characteristic of high marshes. (Levees form on the edge of high marsh creeks and ditches when suspended material in the marsh creeks encounters the friction of marsh vegetation and lower velocities outside of the channel and is deposited. In addition, disposal of excavated material from mosquito ditch construction along the edges of the ditch results in elevated creek borders. These levees favors the growth of plant species normally restricted to higher areas of the marsh.)

B. Problem Description

Common reed is a species of questionable origin which is increasing in prevalence in New England. It is a relatively low value species ecologically, compared to salt marsh species which are generally recognized as having high ecological value. The tendency of common reed to grow in dense stands which exclude other species of vegetation reduces the benefits which accrue to the marsh environment with diversity of vegetation. Although its productivity is apparently quite high, the value of its biomass is limited. Whereas a portion of salt marsh production is exported to the aquatic and terrestrial food webs, common reed production is, to a large extent, unavailable to food webs. It has relatively low value as a food item because of the coarseness of its stems and leaves and its hairy seeds, although it does provide some value to wildlife as cover.

While the mowing which presently occurs maintains salt marsh vegetation, the reduction of tidal flooding which occurs with closure of the gates during the summer decreases the value of the marsh as an estuarine habitat. Regular tidal flushing provides a tidal energy subsidy to the marsh and increases the value of the marsh as an aquatic habitat. Although the marsh presently supports salt marsh vegetation, its productivity is probably reduced because the closure of the tides gates reduces the tidal subsidy and maintains a less desirable plant community overall. The existing marsh type produces less primary productivity. The reduced frequency of tidal flooding does not allow aquatic organisms to periodically use the marsh. The effects of this reduction in aquatic habitat are most evident along the borders of the marsh creeks and ditches where salt marsh cordgrass would normally be present. This habitat type is normally flooded twice daily, providing an opportunity for feeding by aquatic organisms such as killifish (Fundulus sp.) and a permanent habitat for other organisms such as ribbed mussels (Geukensia demissa). Mowing also reduces the wildlife habitat value of the marsh. Birds and mammals which nest and feed on the marsh such as seaside sparrows (Ammospiza maritima) and meadow voles (Microtus pennsylvanicus) are precluded from doing so due to mowing. Therefore, although the the marsh supports salt marsh vegetation, its value is reduced by the current management practice.

C. Vegetative Communities and Ecological Conditions

Vegetation types are shown on Figure B-1. The site was viewed on 1990 aerial photography and in the field on March 19, 1992 and June 17, 1992 to define plant communities. The map shows a generalization of vegetation types across the marsh. Areas were classified according to the species that was visually most abundant over a majority of the map unit. In almost all cases other vegetation types are included within the map units. This is particularly true in the vicinity of ditches and along the upper border where a change in local hydrologic conditions results in a different plant community. The following paragraphs describe the vegetation and the apparent conditions that support the observed vegetation type.

The spike grass/common glasswort (Salicornia europea) map unit covers the largest area of the site. In general, areas dominated by spike grass also contained glasswort. In some locations previous year's growth of glasswort extends over the spike grass canopy, particularly in the most southern portions of the marsh on either side of the main channel. This year's growth of glasswort was mixed with the spike grass where spike grass growth was less dense. Along the edges of the main creek and ditches common reed, salt meadow grass, short salt marsh cordgrass, common glasswort, seaside goldenrod (Solidago sempervirens), and marsh orach (Atriplex patula) are mixed with spike grass.

Spike grass and glasswort are typically abundant in areas that are subject to disturbance (Bertness and Ellison, 1987), waterlogged soils (Miller and Egler, 1950; Niering and Warren, 1980; Bertness and Ellison, 1987), and/or elevated salinity levels (Niering and Warren, 1980). The high abundance of this type on the Leetes Island marsh is probably reflective of a combination of these factors. Poor drainage exists as a result of closure of the gate during the growing season. This condition, coupled with compression of the marsh soils from operation of mowing equipment, could result in waterlogging of the soils. However, the soils in these areas appeared to be dry during the field inspection. This suggests that the lack of periodic tidal exchange may allow concentration of salts in the soil through evapotranspiration favoring spike grass over salt meadow grass. Finally, Miller and Egler (1950) described the effects of long term mowing leading to a spike grass community. They theorized that repeated mowing of the upper border of a marsh lead to decreased plant vigor and elimination of the dead plant material mulch over time leaving bare soil. The reduced cover over the soil was believed to lead to sheet erosion of soil with subsequent colonization of the area by spike grass. The high abundance of spike grass and glasswort at Leetes Island may be indicative of some one or a variety of these factors.

Salt meadow grass is typically the dominant high marsh plant. Its presence suggests locally good conditions of soil drainage, salinity, and flooding. Salt meadow grass appears to increase in dominance in more northern portions of the Leetes Island marsh and toward the upland perimeter in contrast to its more typical prevalence on the lower slope of the marsh (Miller and Egler, 1950; Niering and Warren, 1980; Bertness and Ellison, 1987).

Figure B-1 shows that salt meadow grass is dominant toward the back of the panels on the east side of the marsh surrounding areas of bare substrate and glasswort; on the northern end of the marsh to the east of the main channel; and near the center of the marsh where it is codominant with spike grass in units classified as high marsh.

The panels just north of the sharp corner in the main channel classified as high marsh have fairly irregular microtopography. Spike grass and salt marsh hay are codominants with spike grass dominating in lower areas (where soil drainage is probably poorer) and salt marsh hay dominating where the elevation is slightly higher. The prevalence of salt meadow grass surrounding areas classified as glasswort along the eastern side of the marsh may be a result of reduced accessibility of mowing equipment due to the wet conditions and suggests relatively good conditions of soil drainage and salinity conditions. Miller and Egler (1950) observed that certain pannes on salt marshes they observed had a rim of salt meadow grass around them.

Black grass is present along the upland perimeters of the Leetes Island marsh inward of the common reed (Phragmites australis) zone and in local high spots as is typical of this species (Miller and Egler, 1950; Niering and Warren, 1980; Bertness and Ellison, 1987). It is most common in the southwest corner of the marsh where high tide bush (Iva frutescens) is also present in a thin fringe between the black grass and common reed zones. Black grass occurs as an intermittent fringe marshward of the common reed zone along the majority of the perimeter at a size to small to map. Black grass also occurs in patches on the western side of the marsh and occasionally along mosquito ditches indicating local high spots.

Units mapped as glasswort are located in areas with poor drainage where periodic ponding and evaporation occurs, including the former channel. Most of these areas were ponded during the March field inspection. During the June site visit, most of the standing water was gone. Previous year's and sometimes new growth of glasswort were present in these depressions. Miller and Egler (1950) describe a similar formation of large salt pannes in a Connecticut salt marsh due to plugging of a mosquito ditch and subsequent flooding and ponding of water behind the plug and natural marsh levees. As the water evaporates salts are concentrated in the panne. Apparently, the standing water at the Leetes Island marsh remains long enough to preclude the growth of the marsh perennials which colonize bare areas primarily vegetatively. Glasswort, an annual, colonizes bare patches and pannes rapidly through seeding (Miller and Egler, 1950; Niering and Warren, 1980; Bertness and Ellison, 1987). The ponded areas on the northern and western sides of the marsh were used by black ducks during the winter visit.

Short salt marsh cordgrass occurs in various locations on the marsh, only one of which was visible on the aerial photography. This unit is shown on Figure B-1 on the panel classified as high marsh just north of the sharp corner in the main channel. Other patches of short salt marsh cordgrass are present in various locations except in the glasswort, common reed, and black grass map units. Short salt marsh cordgrass is associated with depressions and pannes (Miller and Egler, 1950). There is no tall or medium height salt marsh cordgrass on the marsh. This type would normally be expected to occur in the regularly flooded zone along ditches and creeks.

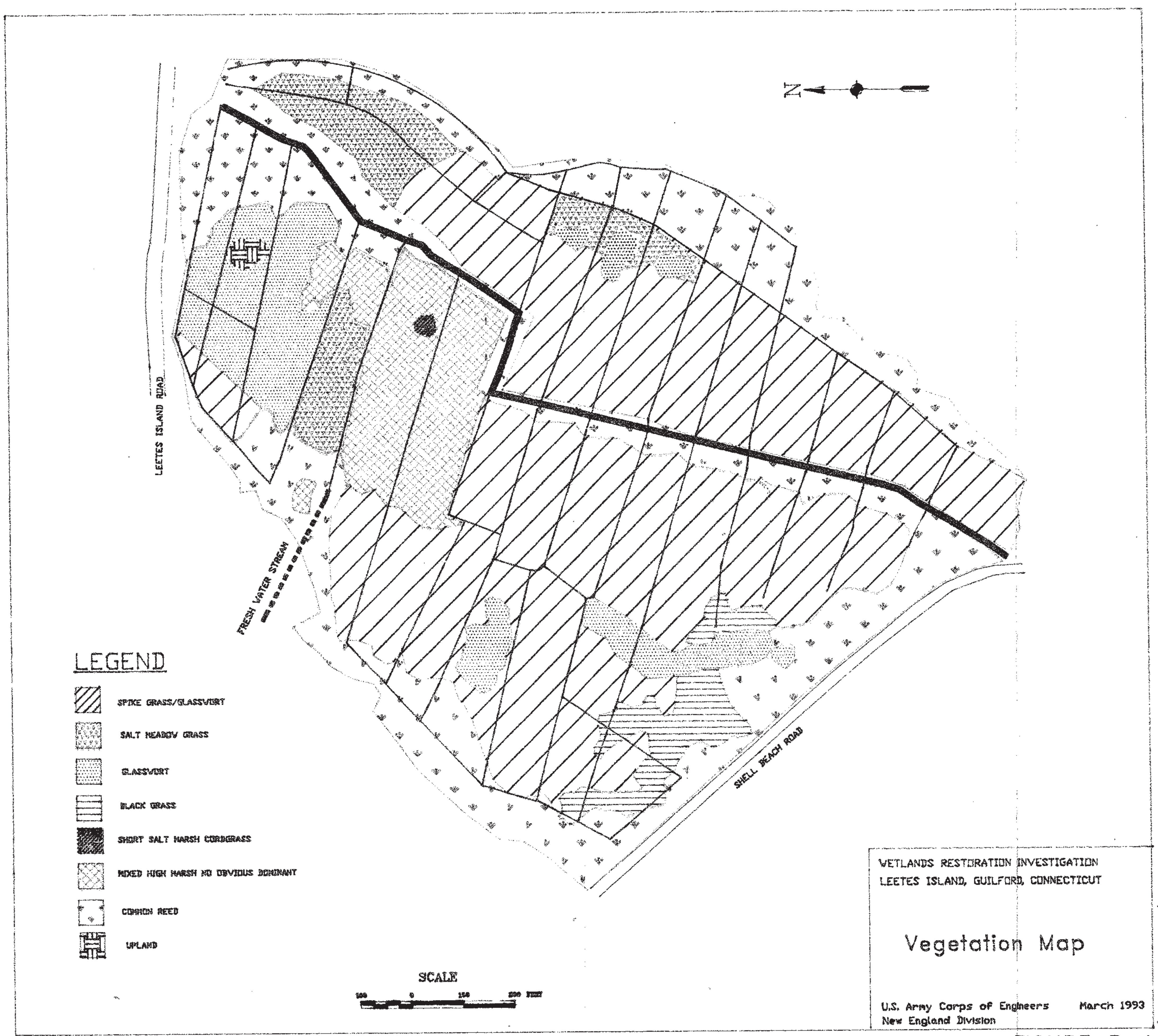

N
LEETES ISLAND ROAD
FRESH WATER STREAM
SHELL BEACH ROAD
LEGEND
SPIKE GRASS/GLASSWORT
SALT MEADOW GRASS
GLASSWORT
BLACK GRASS
SHORT SALT MARSH CORDGRASS
MIXED HIGH MARSH NO OBVIOUS DOMINANT
COMMON REED
UPLAND
SCALE
0
150
WETLANDS RESTORATION INVESTIGATION
LEETES ISLAND, GUILFORD, CONNECTICUT
Vegetation Map
U.S. Army Corps of Engineers
New England Division
March 1993

FIGURE B-1

Common reed is dominant along the upland perimeter, along the edges of many ditches where salt marsh cordgrass would normally dominate under typical hydrologic conditions, and on some broad areas of the marsh, apparently due to the inaccessibility of mowing machinery. The common reed border surrounds entire marsh and the upland island at the northern end of the marsh and borders the majority of the main channel. It covers a wide area where the main channel leaves the salt marsh to the north. It is less dominant along the main channel and ditches on the south eastern end of the marsh.

A remaining vegetation type which could not be shown due to the scale of the mapping occurs along the edges of ditches. Throughout the marsh the diversity of vegetation generally increases within about ten feet of the ditches, except in those locations shown on Figure B-1 which are dominated by common reed. Along the ditches there are localized changes in elevation and hydrologic conditions which support a change in vegetative community. Levees form along the edges of ditches as a result of natural and man induced factors as described by Miller and Egler (1950). Mosquito ditching by hand with convenient disposal of excavated material on the marsh surface adjacent and parallel to the ditch. This resulted in what Miller and Egler described as a turf-line which changed in form over time and resulted in an impedance to drainage. Natural levees form when water in a channel encounters increased friction from vegetation and shallow depths causing deposition of suspended materials. The conditions of less frequent flooding and less saturated soils allow a different vegetative community to develop. At Leetes Island the edges of ditches support combinations of common reed, black grass, salt meadow grass, glasswort, and forbs which vary from the dominant species observed on the majority of a particular panel.

D. Salinities at the Leetes Island Marsh.

Existing salinities in the tidal creeks and the marsh soil water were measured at the Leetes Island marsh for this study. The results of this effort are shown in Table B-1. These results represent only a one-time sampling effort and are therefore of limited usefulness. To describe salinity conditions adequately long-term salinity monitoring would be required.

<u>Creek Salinity</u>. Creek salinity levels ranged from 0-26 ppt generally decreasing to the north (Figure B-2; Table B-1). The salinity in Island Bay was 25 ppt consistent with salinities in Long Island Sound. Salinities in Long Island Sound range from 23 to 35 ppt becoming more saline toward the east (Rhodes, 1989)

<u>Soil Water Salinity</u>. Three holes were dug to collect soil water salinity levels but only three salinities were recorded because three of the holes were dry. Salinities ranged from 14 to 40 ppt.

Table B-1
Salinity sampling results

Date: June 17, 1992
Tide Information: High Tide 4.6 feet NGVD at 1322

Soil Water

Location	Reading ppt	Time of Sample	Surrounding Vegetation
SW-1	40	1502	D. spicata
SW-2	No water	~1510	D. spicata, S. europea
SW-3	26	1531	S. patens
SW-4	No water	~1540	D. spicata
SW-5	No water	~1545	D. spicata
SW-6	14	1556	S. patens
SW-7	No water	1327	S. alterniflora

Creek Water

Location	Reading ppt	Time of Sample	Description
C-1	25	1430	Island Bay
C-2	26	1122	Marsh-end of inlet culvert
C-2	26	1449	Marsh-end of inlet culvert
C-3	5	1142	Major Creek at Stake E-5
C-3	24	1410	Major Creek at Stake E-5
C-4	24	1153	Ditch between panels SE quad.
C-4	9	1518	Ditch between panels SE quad.
C-5	3	1201	Main channel ~450' from culvert
C-5	6	1525	Main channel ~450' from culvert
C-6	0	1230	Main channel at main ditch staff gauge
C-6	0	1545	Main channel at main ditch staff gauge
C-7	0	~1240	Ditch running north-south in NE corner
C-7	0	1559	Ditch running north-south in NE corner

Standing Surface Water

Location	Salinity (ppt)	Time of Sample	Description
S-1	13	1307	S. europea panne NW quad.
S-2	0	1556	S. patens NE quad.

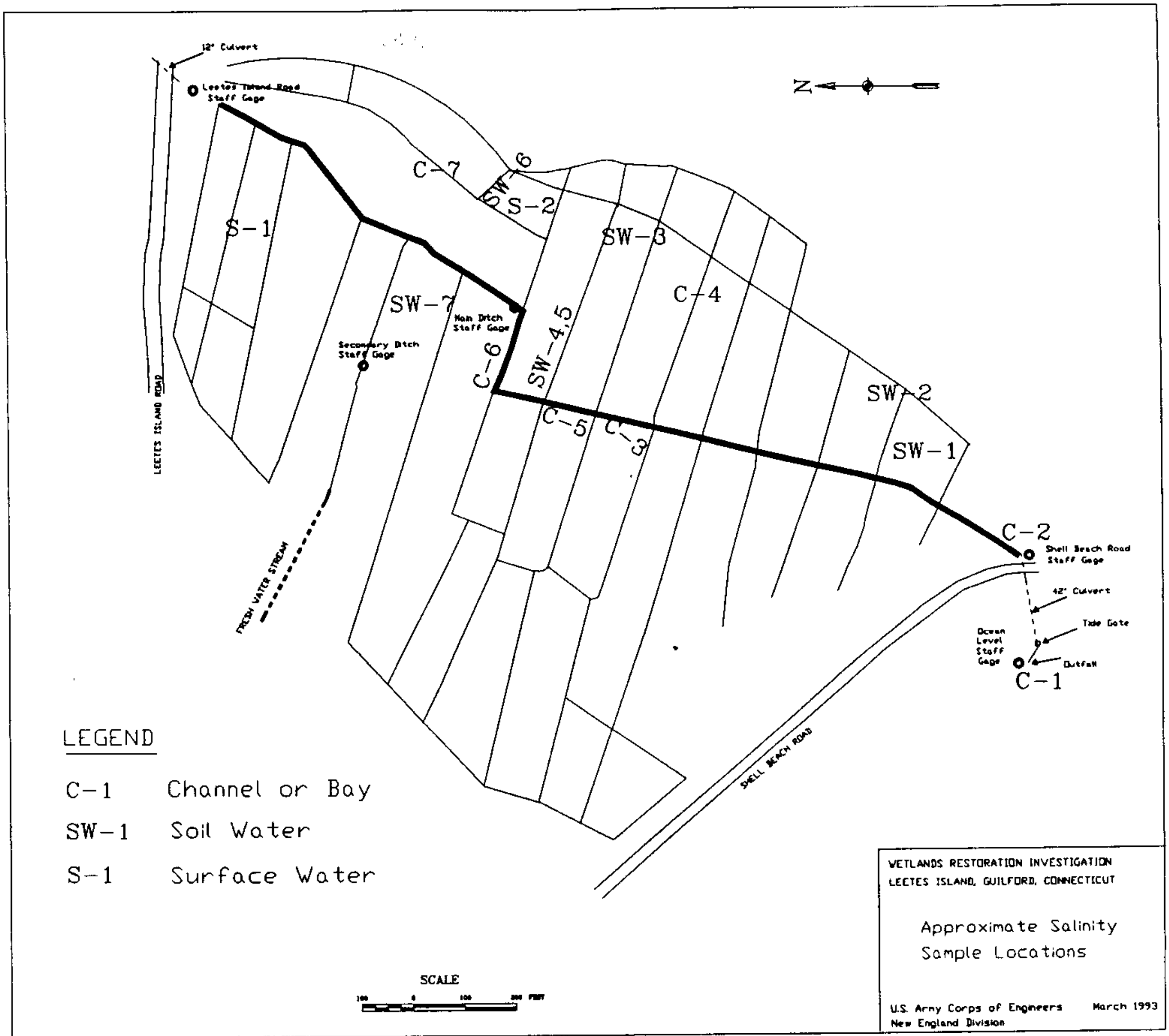

12" Culvert
Leetes Island Road Staff Gage
N
C-7
SW-6
S-2
S-1
SW-3
C-4
SW-7
Main Ditch Staff Gage
Secondary Ditch Staff Gage
C-6
SW-4,5
SW-2
C-5
C-3
SW-1
LEETES ISLAND ROAD
C-2
Shell Beach Road Staff Gage
42" Culvert
Tide Gate
Ocean Level Staff Gage
Outfall
C-1
FRESH WATER STREAM
SHELL BEACH ROAD
LEGEND
C-1 Channel or Bay
SW-1 Soil Water
S-1 Surface Water
SCALE
WETLANDS RESTORATION INVESTIGATION
LEETES ISLAND, GUILFORD, CONNECTICUT
Approximate Salinity Sample Locations
U.S. Army Corps of Engineers
New England Division
March 1993

FIGURE B-2

The results of this very limited sampling were consistent with the results that would be expected based on vegetation type. The higher soil water salinity level (40 ppt) was found in the spike grass and lower levels (26 and 14 ppt) were found in the salt meadow hay areas. In general, these vegetation types can be used to predict soil water salinity levels throughout the marsh. Those areas supporting salt meadow hay or black grass may be expected to have lower salinity levels while areas supporting short salt marsh cordgrass or spike grass may have higher salinity levels (Niering and Warren, 1980). The high relative dominance of spike grass may reflect increased salinity levels on the marsh due to the reduced level of flooding during the growing season when the gate is closed. In the absence of frequent flooding, salts may accumulate through evapotranspiration. This would require long-term monitoring to confirm and conflicts with the suggestion that common reed would dominate the site if mowing were stopped.

II. SALT MARSH ECOLOGICAL/HYDROLOGIC CRITERIA

A. Salinity

Soil Water Salinity. Soil water salinity levels vary spatially and temporally on the marsh. Levels fluctuate with rainfall amounts and interval, season, and flooding frequency and interval with daily inundation below MHW being the major determinant (de Leeuw et al., 1991). Progressing upward in elevation (above MHW), there is a greater time between each inundation with tidal water which allows rainfall and evapotranspiration to increase in influence. This creates conditions of widely fluctuating soil water salinity levels (de Leeuw et al., 1991). de Leeuw et al found that salinity levels in a middle and high marsh varied from less than 5 to more than 30 ppt over a 4-year period.

Requirements for the Elimination of Common Reed. The goal of reintroduction of tidal flow is to increase the depth and frequency of flooding and soil water salinity levels to eliminate common reed and restore conditions which favor the growth of salt marsh vegetation. The level of soil water salinity required to eliminate common reed is estimated at 20 parts per thousand (ppt) based on the following information.

Howard et. al. (1978) summarized results of studies which reported the tolerance of common reed to chlorinity. The values from this report as reported here have been converted to salinity using the equation:

$$\text{Salinity (ppt)} = 1.80655 \text{ Chlorinity (ppt)}$$

(Duxbury, 1971). Results from England indicated that common reed can tolerate areas with salinities up to 22 parts per thousand (ppt) (1.2% chlorinity) and invades marshes where salinity is just below 36 ppt (2% chlorinity). A study on Long Island indicated that common reed growth was good at salinities of 9 ppt (0.48% chloride) and very poor above 23 ppt (1.25% chloride). Howard et al. (1978) concluded that mature plants are limited to areas where soil salinity at 10 cm depth does not exceed about 22 ppt (1.2% chlorinity).

Others have also reported salinities necessary for the control of common reed. Odum et. al. (1984) showed a salinity range for common reed in Maryland between 0.2-10 ppt. According to Mitsch and Gosselink (1986), "Tidal action must be strong enough to maintain salinities above 5 parts per thousand (ppt); otherwise, the salt marsh is replaced by reeds, rushes, and other freshwater aquatic plants." Garbisch (1986) indicated that common reed plants develop mostly above the high water line where salinities are greater than 20 ppt. Sinicrope et. al. (1990) reported that vigorous growth of common reed occurs at salinities of 20 ppt or less. Based on this information, a goal for restoration and maintenance of the Leetes Island Salt Marsh is soil water salinity of 20 ppt or greater.

Salt marsh surface elevation in relation to tidal regime affects the level of soil water salinity. Based on the work of Nuttle (1988) at Belle Isle Marsh in Boston and Hemond and Fifield (1982) at Great Sippewissett Marsh in Massachusetts, the depth of flooding above the marsh may not be the critical factor in determining soil water salinity. Hemond and Fifield indicate that, "Tidal influence in interior regions of marshes over an underlying sandy aquifer may be primarily transmitted to the peat by tidal variations in head in the aquifer" and they describe surface seepage as slight. The period of daily flooding which occurs during the spring period of the tidal cycle floods the soil to an equilibrium position near the marsh surface. These saturated conditions remain until the marsh is no longer flooded as the neap portion of the tidal cycle approaches. In addition, the vertical hydraulic conductivity of marsh sediments is relatively slow (Mitsch and Gosselink, 1986) suggesting that the conditions of greater hydraulic head above the marsh surface with deeper water do not significantly add to marsh soil water levels. This information suggests that there is no detrimental effect on soil water salinity of truncating the highest tide levels to maintain the tidal regime within predetermined limits as long as the soil water is allowed to achieve its equilibrium position near the marsh surface.

B. Tidal Regime

In order to specify a hydrologic regime for the salt marsh, it is necessary to understand the relationship between ecological and hydrologic factors. Salt marsh vegetation zones roughly correlate with certain tidal datums. For salt marsh restorations, on-site measurements of the elevation of the borders between marsh types in an unrestricted portion of the marsh can be used to help predict the results of the restoration of tide levels in the restricted marsh. The evaluation should also take into consideration variations in tidal range, geomorphic characteristics and hydrologic factors. For this study at the Leetes Island Marsh, spot elevations were not collected at the nearby unrestricted marsh; therefore, general criteria for the relationship of tidal regime to vegetation types alone is used to approximate the proposed tidal regime.

High Marsh/Low Marsh Transition. The elevation of the transition from high marsh to low marsh or salt marsh cordgrass marsh is generally described as occurring at about the level of mean high water (MHW). Nixon (1982) questioned the validity of this reference level based on the results of studies he references and because of the unlikelyhood of a "finely tuned botanical indicator" having such a coincidental relationship to an arbitrary datum. Lefor et. al., (1987), however, reported results of a three-year study on Long Island Sound that showed that 98.4% of all observations of salt marsh cordgrass occurred at or below the level of MHW on-site. McKee and Patrick (1988) later questioned these results. They summarized the results of numerous studies along the Atlantic coast and concluded that the upper elevation of salt marsh cordgrass marsh did not coincide with the plane of mean high water or any other tidal datum. They found a significant correlation between the elevation range of salt marsh cordgrass and tidal amplitude: the elevation range of salt marsh cordgrass increases with increasing tidal amplitude by expanding at the upper and lower boundaries.

Since the project site is located on Long Island Sound as were the sites studied by Lefor et al. and has a tidal range within the range of the sites they studied, MHW is a probably a good predictor of the transition between low marsh and high marsh for the Leetes Island site. Based on this relationship and the characteristics of the substrate which are typical of high marsh, the flooding regime for the majority of the marsh should be less frequent than the frequency of flooding at MHW or, as emphasized by Lefor et al., the level of MHW on-site.

High Marsh/Upland Transition. The upper limit of high salt marsh or salt meadow has been estimated at about the level of the highest astronomic tides (Lefor et. al., 1987; Bertness and Ellison, 1987) or at about mean spring high water (MSHW) (Niering and Warren, 1980). Using MSHW as an estimate of the upper limit of the marsh plain allows for higher astronomic tides and storm tides to flood the upper border.

Frequency of Flooding. Since the level of the Leetes Island marsh may have changed due to current management practices, the tidal regime should be developed based on frequency of flooding rather than elevations. Researchers have described a change in surface elevations resulting from conditions similar to those occurring at the Leetes Island marsh. This is significant because a direct correlation can no longer be established between historic plant communities and future plant communities.

Roman et al. (1984) observed that marsh surface elevations were lower in diked and gated common reed marshes with restricted tidal exchange than in unrestricted salt marshes. They speculated that this may result from lowering of the water table and drying out and compaction of the marsh peat as well as increased microbial decomposition of peat and removal of organic matter by fires. Phillips (1986) also observed subsidence on diked marshes separated from regular tidal flooding due to the exclusion of sediment-laden storm and spring tides by dikes. Miller and Egler (1950) and Phillips (1986) also suggested that long term mowing results in the removal of organic matter and can also result in lowering of the marsh surface.

Marsh submergence and exposure requirements were summarized by Mitsch and Gosselink (1986) based on information presented by Chapman (1960) as follows:

	Submergences		Maximum Period of Continuous Exposure, days
	per day in daylight	per year	
Upper marsh	<1	<360	>=10
Intertidal Marsh	>1.2	>360	<=9

Source <u>Wetlands</u> (Mitsch and Gosselink, 1986) from Chapman (1960)

As previously discussed, plant communities are generally segregated according to tidal datums. Tidal datums in turn are associated with certain flooding frequencies. Mean spring high water (MSHW), the upper elevation of the marsh plain, is the mean of tides of increased range occurring semimonthly as a result of the moon being new or full (NOS, 1992). In terms of the minimum number of flooding tides, therefore, MSHW would translate to about 2 flooding tides per month or 24 flooding tides per year. The number of flooding tides necessary to maintain salt marsh would also be affected by the quantity of freshwater inflow and geomorphic conditions on and around the marsh. But, as a guide, it appears that slightly less than 24 flooding tides per year would be sufficient to maintain salt marsh on the plain beneath the upper border of the marsh or high tide bush zone.

A certain number of tides each year exceed the level of MSHW up to the highest astronomic tide level. These tides provide an increased depth of flooding over the marsh surface to perform such functions as transporting flotsam and detritus. These highest astronomic tides also provide occasional tidal flooding of the upper border of the marsh.

MHW, which roughly correlates with the upper level of the low salt marsh, occurs at an elevation that is reached at a frequency of once per day. Since the low marsh extends from about MHW to MTL, the frequency of flooding should be 1 to 2 times per day.

In summary, the following are the frequency of flooding criteria for the proposed hydrologic regime:

	Frequency of Flooding
Low Marsh	1-2/day
High Marsh Plain	2-28/month
Upper Border	<2/month

III. MARSH REACTION TO THE NEW HYDROLOGIC REGIME

The likely result of the proposed tidal regime is a reduction in the prevelance of common reed and the restoration of conditions suitable for the growth of salt marsh.

The Leetes Island marsh shows signs of the effects of its present management for haying. The existing predominance of salt marsh vegetation would not likely exist if mowing were discontinued. As previously mentioned, Roman et. al. (1984) suggested that mowing for salt hay at the Leetes Island marsh is deterring the encroachment of common reed into the salt marsh and that if mowing were discontinued, common reed would probably rapidly spread and dominate the system. While this is probably true for the majority of the marsh, areas of locally high soil water salinity due to evapotranspiration would likely remain as salt marsh if the gates were operated as they are now. Therefore, the goal of the proposed tidal regime is to change the unmowed condition of common reed dominance rather than the existing plant community. Periodic pulsing of saline groundwater and flooding of the marsh surface when the tidal regime is restored, will increase soil water salinity levels to create conditions suitable for the maintenance of salt marsh. The effects of restoration of tidal exchange has been shown to result in the restoration of salt marsh (Niering and Warren, 1980; Roman et al., 1984; Bongiorno et al. 1984; and Sinicrope et al. 1990).

The future vegetative composition of the marsh is dependent on existing elevations as they will be affected by the proposed tidal regime. At the Leetes Island marsh, the difference between the MHW level and the MSHW level, the estimated upper and lower limits of the high marsh plain, is only 0.4 ft. Because of this very narrow range, it is difficult to develop a sophisticated estimate of the on-site elevation range of various plant community types. Appendix A indicates that the top of ditches occurs at about elevation 0.5 foot NGVD. This is the proposed upper limit of low marsh. Any areas below this elevation will revert to low marsh with the new tidal regime and any elevations above this level up to the elevation of the highest astronomic tides will revert to high marsh. (This specific elevation is a best estimate. The actual elevation may be slightly higher or lower. In addition, due to delay in tidal flow, the elevation of the upper limit of high marsh may be slightly lower toward the back of the marsh near Leetes Island Road. Therefore, all of the discussion based on this level is also estimated.) This is based on two assumptions: 1) The geomorphic conditions on the marsh will allow a sufficient increase in salinity; and 2) Low areas will drain properly to allow formation of low marsh rather than pannes or ponds. Concerning the first assumption, there will probably be a common reed fringe around the upland edge of the marsh and where freshwater inflow occurs because of reduced salinity in these areas. Concerning the second assumption, some realignment of ditches on the marsh using a system such as open marsh water management will have to be applied to ensure that periodic flooding and draining occurs.

Most of the area to the east of the main channel is at or above elevation 0.5 ft NGVD and should remain as high salt marsh. The large area of common reed area along the eastern edge of this area is situated behind a ditch running north and south. While its present condition is most likely a result of the physical barrier it creates for mowing equipment, it may remain in common reed dominance even after the new hydrologic regime is established. The ditch may serve to intercept saline ground water flow through salt marsh peat reducing soil water salinity levels. The connection to the upland surface and groundwater without the periodic pressure of the saline water may cause conditions suitable for the growth of common reed. This condition has been observed at other locations. Filling this ditch with material with good hydraulic conductance capacity could reclaim more of this area.

The area to the west of the ditch from the entrance to about three panels down from Leetes Island Road for a width of about 100-150 ft is also at or above elevation 0.5 ft NGVD and should remain as salt marsh. High salt marsh should also be restored for a width of about 100 ft along the western upland edge of the marsh.

The area presently classified as glasswort where the historic channel existed and on the northern three panels of the marsh west of the main channel are below elevation 0.5 ft NGVD. These areas will continue to exist as pannes under the proposed tidal regime unless drainage is improved.

These areas experience poor drainage because of the levee formation which occurs along creeks and ditches. As previously discussed levees occur frequently on ditched tidal marshes due to the convenient disposal of excavated material along the edges of the ditches and in natural marshes because greater quantities of suspended material are deposited nearer the creek edges due to the filtering effect of vegetation and lower velocities on the marsh plain (Miller and Egler, 1950; Niering and Warren, 1980; Nixon, 1982; Stoddart et al., 1989). This formation may be more pronounced on the Leetes Island marsh as a result of subsidence of the marsh surface due to mowing and drying due to the closure of gates during the growing season and possibly compression from the construction of Leetes Island Road. Phillips (1986) observed that many of the salt meadow grass marshes around Delaware Bay that had historically been farmed for hay experienced widespread subsidence. He indicated that many high marshes which were once farmed are now inundated by each tidal cycle due partially to the annual removal of biomass. In addition, the relocation of the inlet channel created an unusual condition of a low area that does not slope toward a creek or channel.

Ponding or waterlogged soil conditions in the interior of the marsh would maintain conditions suitable for these large pannes by restricting drainage. Marsh edges higher than the marsh plain cause two dimensional flow (Nuttle, 1988) which can presumedly allow increases in salt concentrations and lower drainage rates. High marsh areas experiencing these conditions of poor drainage and dominance by short salt marsh cordgrass and forbs may have lower productivity than a salt meadow hay/spike grass marsh (Niering pers comm). When the new tidal regime is initiated, management measures such as manipulation of the precise water level or placing notches and ditches of creeks through these levees should be considered. These management measures could result in the creation of a medium height salt marsh cordgrass community.

REFERENCES

Bertness, M.D. and A.M. Ellison. 1987. Determinants of pattern in a New England salt marsh plant community. Ecological Monographs, Vol. 57, No. 2, pp.129-147.

Bongiorno, S.F., J.R. Trautman, T.J. Steinke, S. Kawa-Raymond, and D. Warner. 1984. A study of restoration in Pine Creek salt marsh, Fairfield, Connecticut. Proceedings of the Eleventh Annual Conference on Wetlands Restoration and Creation, F.J. Webb, Editor, Hillsborough Community College, Tampa, Florida.

Chapman, V.J. 1960. Salt Marshes and Salt Deserts of the World. Interscience Publications, New York.

Cowardin, L.M., V. Carter, F.C. Golet, E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service, Washington, D.C. FWS/OBS-79/31

de Leeuw, J., A. van den Dool, W. de Munck, J. Nieuwenhuize, and W.G. Beeftink. 1991. Factors influencing the soil salinity regime along an intertidal gradient. Estuarine, Coastal, and Shelf Science, Vol. 32, pp 87-97.

Duxbury, A.C. 1971. The Earth and Its Oceans. Addison-Wesley Publishing Co., Reading, Mass. 381 pp.

Garbisch, E.W. 1986. Highways and wetlands; compensating wetland losses. US Department of Transportation, Federal Highway Administration, Washington, D.C.

Hemmond H.F. and J.L. Fifield. 1982. Subsurface flow in salt marsh peat: A model and field study. Limnology Oceanography, 27(1). pp. 126-136.

Howard, R., D.G. Rhodes and J.W. Simmers. 1978. A review of the biology and potential control techniques for Phragmites australis. IND D-78-26. U.S. Army Engineer, Waterways Experiment Station, Vicksburg, MS.

Lefor, M.W., W.C. Kennard, and D.L. Civco. 1987. Relationships of salt-marsh plant distributions to tidal levels in Connecticut, USA. Environmental Management, Vol. 11, No. 1, pp 61-68.

McKee, K.L. and W.H. Patrick, Jr. 1988. The relationship of smooth cordgrass (Spartina alterniflora) to tidal datums: a review. Estuaries, Vol. 11, No. 3, pp. 143-151.

Mendelsshon I.A. and E.D. Seneca. 1980. The influence of soil drainage on the growth of salt marsh cordgrass Spartina alterniflora in North Carolina. Estuarine and Coastal Marine Science, Vol. II, pp 27-40.

Miller, W.R. and F.E. Egler. 1950. Vegetation of the Wequetequock-Pawcatuck tidal-marshes, Connecticut. Ecological Monographs 20:143-172.

Mitsch, W. J. and J. G. Gosselink. 1986. Wetlands. Van Nostrand Reinhold Company Inc., New York. 539 pp.

National Ocean Service (NOS). 1989. Tide Tables 1990, High and Low Water Predictions, East Coast of North and South America Including Greenland. US Department of Commerce, National Oceanic and Atmospheric Administration, Rockville, Maryland.

Niering, W.A. and R.S. Warren. 1980. Vegetation patterns and processes in New England salt marshes. BioScience, Vol. 30, No. 5.

Nixon, S.W. 1982. The Ecology of New England High Salt Marshes: A Community Profile. FWS/OBS-81-55. U.S. Fish and Wildlife Service. Office of Biological Services, Washington, D.C. 70 pp.

Nuttle, W. K. and J. W. Harvey. 1987. Geomorphological control on subsurface transport in two salt marshes. Proceedings: National Wetland Symposium, Wetland Hydrology, Association of State Wetland Managers, Inc., Berne, NY.

Nuttle, W. K. 1988. The extent of lateral water movement in the sediments of a New England salt marsh. Water Resources Research, Vol. 24, No. 12.

Odum, W.E., T.J. Smith III, J.K. Hoover, and C.C. McIvor. 1984 The ecology of tidal freshwater marshes of the United States east coast: a community profile. U.S. Fish and Wildlife Service. FWS/OBS-83/17. 177pp.

Phillips, J.D. 1986. Coastal submergence and marsh fringe erosion. Journal of Coastal Research, Fort Lauderdale. pp. 427-436.

Rhodes, K. Long Island Sound Study, Fact Sheet No. 4. Connecticut Sea Grant Marine Advisory Program and New York Sea Grant Extension Program. CT-SG-89-03.

Roman, C.T., W.A. Niering, and R.S. Warren. 1984. Salt marsh vegetation change in response to tidal restriction. Environmental Management, Vol. 8, No. 2.

Sinicrope, T.L., P.G. Hine, R.S. Warren, W.A. Niering. 1990. Restoration of an impounded salt marsh in New England. Estuaries, Vol. 13, No. 1.

Stoddart, D.R., D.J. Reed, and J.R. French. 1989. Understanding salt-marsh accretion, Scolt Head Island, Norfolk, England. Estuaries, Vol. 12, No. 4. pp 228-236.

Tiner, R. W., Jr. 1987. A Field Guide to Coastal Wetland Plants of the Northeastern United States. The University of Massachusetts Press, Amherst, MA.

APPENDIX C

TIDAL MONITORING DATA

Table C-1. Tidal Monitoring Data, March 19, 1992

Gage at outlet		Gage at Headwall		Gage at main ditch		Gage at side ditch		Gage at Leetes Is Rd	
time	elev,ft, NGVD	time	elev,ft, NGVD	time	elev,ft, NGVD	time	elev,ft, NGVD	time	elev,ft, NGVD
6.45	-1.60	6.45	0.75	6.45		6.45		6.45	1.20
7.00	-1.60	7.00	0.75	7.00	0.90	7.00		7.00	
7.30	-0.10	7.30	0.70	7.30		7.30		7.30	
7.40	0.00	7.40		7.40		7.40		7.40	
7.55	0.40	7.55	0.75	7.55		7.55		7.55	
8.00	0.50	8.00	0.80	8.00		8.00		8.00	
8.10	0.95	8.10	0.95	8.10		8.10		8.10	
8.20	1.00	8.20	1.05	8.20		8.20		8.20	
8.25	1.20	8.25	1.10	8.25		8.25		8.25	1.10
8.35	1.40	8.35	1.15	8.35		8.35		8.35	
8.40	1.60	8.40	1.20	8.40	1.10	8.40		8.40	
8.45	1.70	8.45	1.20	8.45		8.45		8.45	
8.50	1.80	8.50	1.25	8.50		8.50		8.50	
8.55	1.95	8.55	1.25	8.55		8.55		8.55	
9.00	2.05	9.00	1.25	9.00		9.00		9.00	
9.30	2.70	9.30	1.35	9.30		9.30		9.30	
10.00	3.60	10.00	1.40	10.00	1.30	10.00		10.00	1.20
11.00	4.40	11.00	1.50	11.00		11.00		11.00	1.25
11.15	4.40	11.15	1.55	11.15		11.15		11.15	
11.25	4.40	11.25	1.55	11.25	1.40	11.25		11.25	1.30
11.35	4.35	11.35	1.58	11.35	1.42	11.35	1.25	11.35	
11.45	4.30	11.45	1.60	11.45		11.45	1.30	11.45	1.35
12.00	4.05	12.00	1.60	12.00	1.45	12.00	1.33	12.00	1.35
12.20	3.80	12.20	1.62	12.20		12.20	1.35	12.20	1.38
12.35	3.55	12.35	1.62	12.35	1.50	12.35	1.40	12.35	1.40
12.45	3.30	12.45	1.62	12.45		12.45	1.45	12.45	1.45
13.00	3.00	13.00	1.62	13.00	1.53	13.00	1.48	13.00	1.45
13.20	2.55	13.20	1.63	13.20	1.55	13.20	1.50	13.20	1.48
13.35	2.05	13.35	1.63	13.35	1.58	13.35	1.50	13.35	1.50
13.50	1.75	13.50	1.62	13.50	1.58	13.50	1.53	13.50	1.50
14.00	1.60	14.00	1.61	14.00	1.58	14.00		14.00	1.55
14.25	1.15	14.25	1.52	14.25	1.58	14.25	1.53	14.25	1.55
15.25	0.85	15.25	1.35	15.25		15.25		15.25	1.55
16.00	-0.85	16.00	1.28	16.00	1.42	16.00		16.00	
16.30	-1.50	16.30	1.22	16.30		16.30		16.30	
16.35	-1.55	16.35		16.35		16.35		16.35	1.49

Table C-2. Tidal Monitoring Data, April 7, 1992

Gage at outlet		Gage at Headwall		Gage at main ditch		Gage at side ditch		Gage at Leetes Is Rd	
time	elev,ft, NGVD	time	elev,ft, NGVD	time	elev,ft, NGVD	time	elev,ft, NGVD	time	elev,ft, NG
9.20	-1.60	9.20	0.90	9.20	1.15	9.20	1.20	9.20	1.35
10.30	-1.00	10.30	0.80	10.30		10.30	1.15	10.30	
10.45	-0.50	10.45	0.80	10.45	1.00	10.45		10.45	1.30
11.00	-0.30	11.00	0.75	11.00		11.00		11.00	
11.15	-0.10	11.15	0.80	11.15		11.15	1.10	11.15	
11.30	0.45	11.30	0.85	11.30	1.00	11.30	1.10	11.30	1.20
11.40	0.75	11.40	0.90	11.40		11.40		11.40	
11.45	0.70	11.45	0.90	11.45		11.45		11.45	
11.55	0.95	11.55	1.00	11.55		11.55		11.55	
12.05	1.10	12.05	1.10	12.05	1.00	12.05	1.10	12.05	
12.15	1.30	12.15	1.20	12.15		12.15		12.15	
12.30	1.50	12.30	1.20	12.30		12.30	1.10	12.30	1.20
12.40	1.75	12.40	1.30	12.40	1.10	12.40	1.10	12.40	
13.10	2.15	13.10	1.30	13.10		13.10		13.10	1.20
13.25	2.50	13.25	1.35	13.25		13.25		13.25	
13.35	2.70	13.35	1.40	13.35	1.25	13.35	1.10	13.35	
13.45	2.90	13.45	1.40	13.45		13.45		13.45	
13.55	3.00	13.55	1.40	13.55		13.55		13.55	
14.10	3.20	14.10	1.45	14.10	1.30	14.10	1.15	14.10	1.25
14.25	3.35	14.25	1.45	14.25	1.30	14.25		14.25	
14.35	3.35	14.35	1.50	14.35		14.35	1.20	14.35	
14.45	3.35	14.45	1.50	14.45		14.45		14.45	
15.00	3.40	15.00	1.50	15.00	1.50	15.00	1.20	15.00	1.30
16.35	2.15	16.35	1.55	16.35	1.45	16.35	1.30	16.35	
16.45	1.85	16.45	1.55	16.45		16.45		16.45	1.40
17.00	1.50	17.00	1.50	17.00	1.45	17.00	1.40	17.00	
17.15	1.20	17.15	1.40	17.15		17.15		17.15	
17.30	0.95	17.30	1.35	17.30	1.43	17.30	1.40	17.30	
17.40	0.80	17.40	1.35	17.40		17.40		17.40	
17.50	0.55	17.50	1.30	17.50		17.50		17.50	
18.00	0.30	18.00	1.25	18.00	1.40	18.00	1.40	18.00	1.45
18.15	0.05	18.15	1.20	18.15		18.15		18.15	
18.30	-0.25	18.30	1.15	18.30	1.35	18.30	1.35	18.30	
18.40	-0.35	18.40	1.15	18.40		18.40		18.40	
18.50	-0.60	18.50	1.15	18.50		18.50		18.50	1.45

Table C-3. Tidal Monitoring Data, April 16, 1992

Gage at outlet		Gage at Headwall		Gage at main ditch		Gage at side ditch		Gage at Leetes Is Rd	
time	elev,ft, NGVD	time	elev,ft, NGVD	time	elev,ft, NGVD	time	elev,ft, NGVD	time	elev,ft, NG
7.15	-1.00	7.15	0.50	7.15		7.15		7.15	1.15
7.50	-0.25	7.50	0.40	7.50	0.70	7.50		7.50	
8.05	0.10	8.05	0.50	8.05		8.05		8.05	
8.15	0.45	8.15	0.63	8.15		8.15		8.15	
9.00	1.25	9.00	1.07	9.00	0.80	9.00		9.00	1.03
9.25	1.80	9.25	1.25	9.25		9.25		9.25	1.05
9.45	2.25	9.45	1.35	9.45	1.18	9.45		9.45	
10.00	2.82	10.00	1.38	10.00		10.00		10.00	
10.15	2.85	10.15	1.40	10.15		10.15	1.00	10.15	1.10
10.30	3.05	10.30	1.42	10.30	1.20	10.30		10.30	
10.40	3.20	10.40	1.43	10.40	1.23	10.40	1.03	10.40	1.12
10.50	3.20	10.50	1.43	10.50		10.50	1.05	10.50	
11.05	3.45	11.05	1.45	11.05	1.24	11.05	1.07	11.05	1.15
11.25	3.25	11.25	1.45	11.25	1.28	11.25	1.09	11.25	
11.45	3.25	11.45	1.48	11.45	1.30	11.45		11.45	1.20
11.50	3.10	11.50	1.48	11.50		11.50	1.12	11.50	
12.00	3.10	12.00	1.50	12.00	1.32	12.00	1.13	12.00	1.20
12.30	2.50	12.30	1.48	12.30	1.33	12.30		12.30	
12.45	2.25	12.45	1.45	12.45	1.33	12.45	1.20	12.45	
13.00	2.00	13.00	1.45	13.00	1.33	13.00		13.00	1.30
13.10	1.60	13.10	1.40	13.10		13.10	1.22	13.10	
13.20	1.35	13.20	1.40	13.20		13.20		13.20	
13.35	0.75	13.35	1.20	13.35		13.35		13.35	
13.50	0.55	13.50	1.18	13.50	1.30	13.50	1.25	13.50	1.30
14.00	0.45	14.00	1.13	14.00	1.25	14.00	1.25	14.00	
14.10	0.00	14.10	1.05	14.10		14.10	1.25	14.10	
14.20	-0.20	14.20	1.02	14.20		14.20	1.25	14.20	
14.45	-0.60	14.45	0.98	14.45	1.20	14.45		14.45	1.30
14.55	-0.95	14.55	0.95	14.55		14.55		14.55	
15.20		15.20		15.20	1.10	15.20	1.20	15.20	1.30